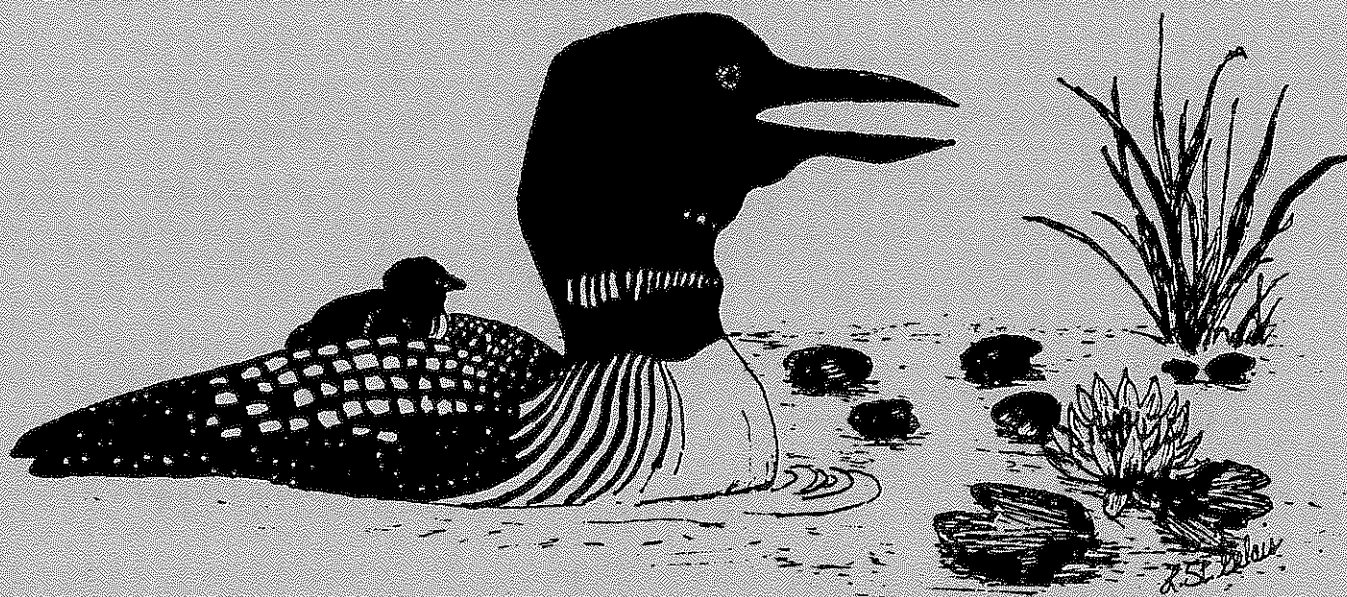


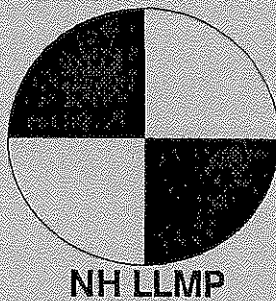
SWAIN'S LAKE 1994

NH LAKES LAY MONITORING PROGRAM



NEW HAMPSHIRE LAKES LAY MONITORING PROGRAM

by
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&
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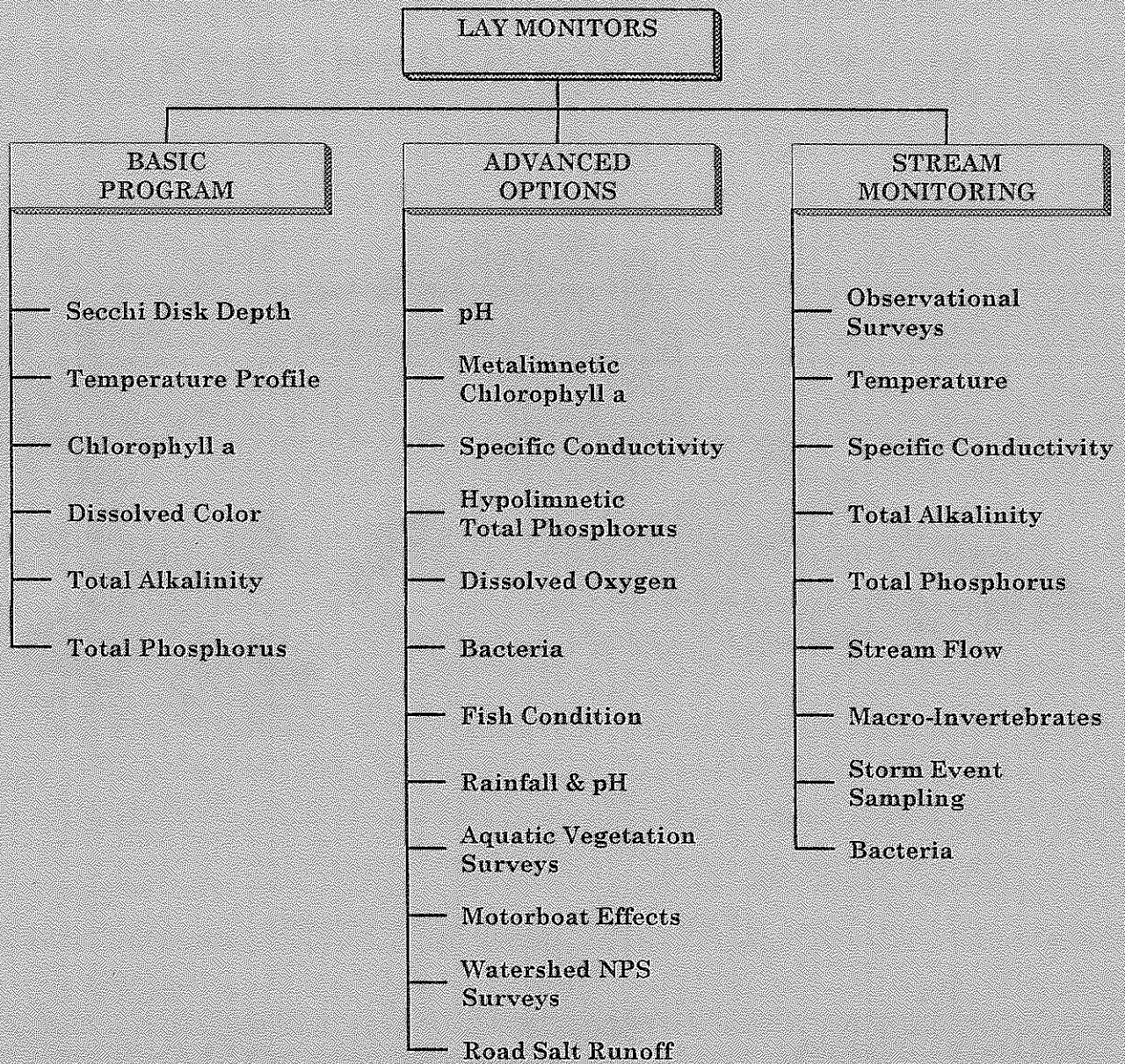
FRESHWATER BIOLOGY GROUP
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Durham

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To obtain more information about the NH Lakes Lay Monitoring Program
(NH LLMP) contact the Coordinator (J.Schloss) at (603) 862-3848
Dr. Baker at 862-3845 or Dr. Haney at 862-2106

PARAMETERS SAMPLED

NH LAKES LAY MONITORING PROGRAM



Freshwater Biology Group (FBG) corroboration with the lay monitor data includes assessment of 1) physical parameters (water transparency, temperature profiles, light transmission profiles and water color); 2) chemical parameters (dissolved oxygen profiles, "free" carbon dioxide, total alkalinity, pH, total phosphorus and specific conductivity profiles); 3) biological parameters (chlorophyll a, phytoplankton community and zooplankton community). Note: in addition to the above parameters, other measurements are often collected at the discretion of the FBG or at the request of the lake association.

PREFACE

This report contains the findings of a water quality survey of Swain's Lake, Barrington, New Hampshire, conducted in the summer of 1994 by the **Freshwater Biology Group (FBG)** of the University of New Hampshire and the Swain's Lake Association.

The report is written with the concerned lake resident in mind and contains a brief, non-technical summary of 1994 results as well as more detailed "Introduction" and "Discussion" sections. Graphic display of data is included, in addition to listings of data in appendices, to aid visual perspective.

ACKNOWLEDGMENTS

1994 was the sixth year of participation in the **Lakes Lay Monitoring Program (LLMP)** for the Swain's Lake Association. The Lay Monitors of Swains Lake were Elaine and Frank Cullen, Peter and Carol Kevin, Forrest and Miriam Miner, Don Newton, Ed Sorel and Norm and Wendi Tremblay. Carol Kevin again coordinated the volunteer monitoring efforts on Swain's Lake and acted as liaison to the **Freshwater Biology Group (FBG)**. The **Freshwater Biology Group** congratulates the Lay Monitors on the quality of their work, and the time and effort put forth. We encourage other interested members of the Swain's Lake Association to continue monitoring during the 1995 sampling season. Funding for the water quality monitoring program was provided by the Swain's Lake Association.

The **Freshwater Biology Group** is a not-for-profit research program co-supervised by Dr. Alan Baker and Dr. James Haney and coordinated by Jeffrey Schloss. Members of the **FBG** summer field team included, Robert Craycraft (laboratory and field coordinator), Neim Hoang Dang, Tracy Grazia, Sean Proll and John Raifsnider. Other **FBG** staff assisting in the fall included Jessica Chappel and Rick Falzone while Lisa St. Gelais helped design our 1994 report format and the 1994 report cover.

The **FBG** acknowledges the University of New Hampshire Cooperative Extension for funding and furnishing

office, laboratory and storage space. The College of Life Sciences and Agriculture provided accounting support and the UNH Office of Computer Services provided computer time and data storage allocations.

Participating groups in the **LLMP** include: The Center Harbor Bay Conservation Commission, Derry Conservation Commission, Dublin Garden Club, Governor's Island Club Inc., Meredith Bay Rotary Club, Nashua Regional Planning Commission, The New Hampshire Audubon Society, Society for Protection of Lakes and Streams, Walker's Pond Conservation Society, United Associations of Alton, the associations of Baboosic Lake, Berry Bay, Bow Lake Camp Owners, Caanan Street, Canobie Lake, Chalk Pond, Chesham Pond, Lake Chocorua, Cunningham Pond, Crystal Lake, Dublin Lake, Glines Island, Goose Pond, Great East Lake, Lake Kanasatka Watershed, Langdon Cove, Long Island Landowners, Lovell Lake, March's Pond, Mendum's Pond, Merrymeeting Lake, Milton Ponds Lake Lay Monitoring, Mirror Lake (Tuftonboro), Moultonborough Bay, Lake Winnepesaukee, Naticook Lake, Newfound Lake, Nippo Lake, Pea Porridge Pond, Pemaquid Watershed, Silver Lake (Madison), Silver Lake (Tilton), Squam Lakes, Sunset Lake, Wentworth Lake and the towns of Alton, Amherst, Enfield, Errol, Madison, Meredith, Merrimack, Milan, Strafford and Wolfeboro.

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INTRODUCTION

The New Hampshire Lakes Lay Monitoring Program

1994 marked the seventeenth year of operation for the **NH Lakes Lay Monitoring Program (LLMP)**. The LLMP has grown from a university class project on Chocorua Lake and pilot study on the Squam Lakes to a comprehensive state-wide program with over 500 volunteer monitors and more than 100 lakes participating. Originally developed to establish a data-base for determining long-term trends of lake water quality for science and management, the program has expanded by taking advantage of the many resources that citizen monitors can provide. The **NH LLMP** has an international reputation as a successful cooperative monitoring, education and research program. Current projects include: use of volunteer generated data for non-point pollution studies using high tech analysis system (Geographic Information Systems and Satellite Remote Sensing), intensive watershed monitoring for the development of lake nutrient budgets, and investigations of water quality and indicator organisms (food web analysis, fish condition, and stream invertebrates). The key ingredients responsible for the success of the program include innovative funding and cost reduction, assurance of credible data, practical sampling protocols and, most importantly, the interest and motivation of our volunteer monitors.

The 1994 sampling season was another exciting year for the **New Hampshire Lakes Lay Monitoring**

Program. National recognition for the high quality of work by you, the volunteer monitors, continued with awards, requests for program information and invitations to speak at national conferences (Figure 1). Our Geographic

Figure 1. Awards and Recognition.

AWARDS

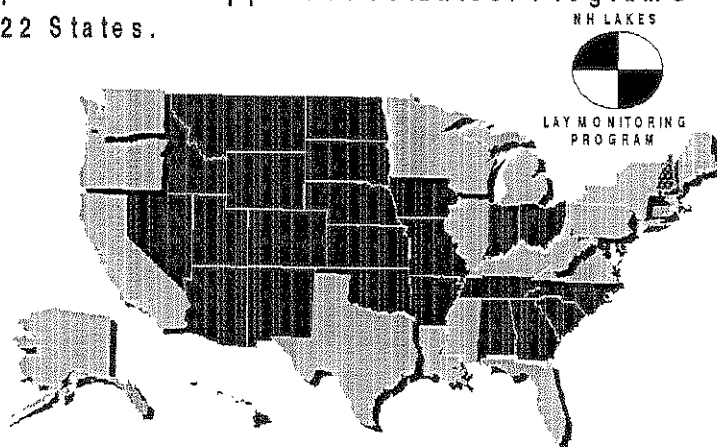


and



1983- N H Environmental Law Council
1984- Governor's Volunteerism Award
1985- CNN Science & Technology Today
1988- Governor's 'Gift' request funded
1990- New Hampshire Journal on PBS
1991- Renew America Success Award
- Environmental Success Index
- UN Environmental Programme
- Soviet Embassy Reception
- White House Environment Briefing
1992- EPA Administrators Award
- Environmental Exchange Network
1993- NH Lakes Association
1994- Fourth National Citizens' Volunteer Monitoring Conference

NH LLMP Directly Involved with the Initiation, Expansion or Support of Volunteer Programs in 22 States.



Information System study of Squam Lake was highlighted at the Fourth National Citizens' Volunteer Monitoring Conference held last April in Portland, Oregon. We were also invited to highlight our **NH LLMP/Cooperative Extension** relationship at a southeast re-

gional meeting for US Department of Agriculture water quality staff held in Florida. On the local front, the NH Senate Agricultural and Environment committee and the NH House Resource, Recreation and Development Committee were briefed on **NH LLMP** activities. We continue to be listed as a model citizen monitoring program on the Environmental Success Index of Renew America and on the Environmental Network Clearinghouse and were recently acknowledged by the National Awards Council for Environmental Sustainability. To date, the approach and methods of the **NH LLMP** have been adopted by new or existing programs in twenty two states and nine countries!

Importance of Long-term Monitoring

A major goal of a monitoring program is to identify any short or long-term changes in the water quality of the lake. Of major concern is the detection of cultural eutrophication: increases in the productivity of the lake, the amount of algae and plant growth, due to the addition of nutrients from human activities. Changes in the natural buffering capacity of the lakes in the program is also a topic of great concern, as New Hampshire receives large amounts of acid precipitation, yet most of our lakes contain little mineral content to neutralize this type of pollution.

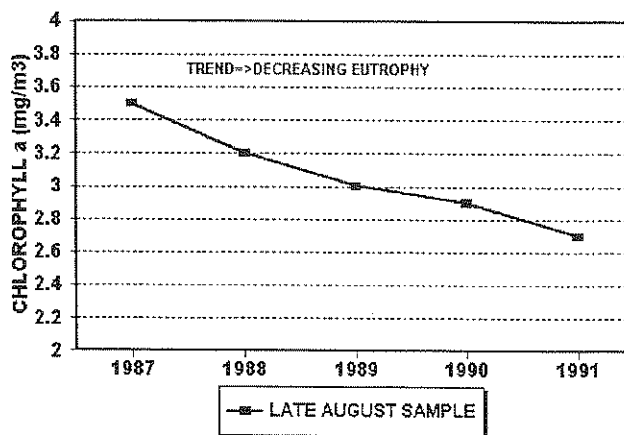
For almost a decade and a half, data collected weekly from lakes participating in the New Hampshire Lakes Lay Monitoring Program have indicated there is quite a variation in water quality indicators through the open water season on the majority of lakes. Short-term differences may be due to variations in weather, lake use, or other chance events. Monthly sampling of a

lake during a single summer provides some useful information, but there is a greater chance that important short-term events such as algal blooms or the lake's response to storm run-off will be missed. These short-term fluctuations may be unrelated to the actual long-term trend of a lake or they may be indicative of the changing status or "health" of a lake.

To determine if a change in water quality is occurring, a lake must be sampled on a frequent basis over a substantial amount of time. A poorly designed sampling program may even mislead the investigator away from the actual trend: Consider the hypothetical lake in Figure 2. Sampling only once a year during August from 1987 to 1991 would produce a plot (Fig. 2) suggesting a decrease in eutrophication. The actual

Figure 2.

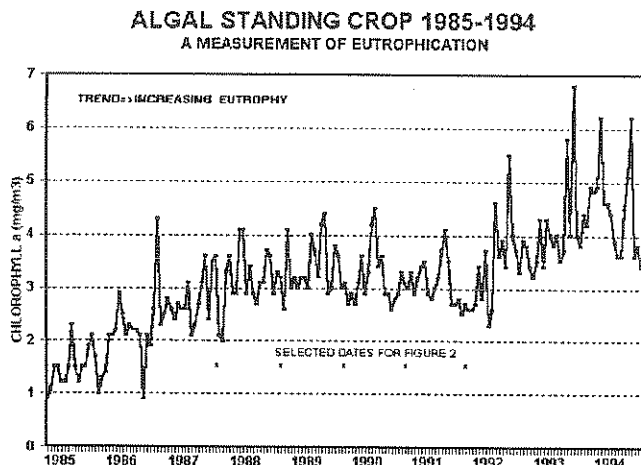
ALGAL STANDING CROP 1987-1991
LATE SEASON SAMPLES FROM FIGURE 3



long-term trend of the lake, increasing eutrophy, can only be clearly discerned by sampling additional times a year for a ten year period (Fig. 3). Frequent monitoring carried out over the course of many summers can provide the information required to distinguish between short-term fluctuation ("noise") and

long-term trends ("signal"). To that end, the lake must establish a long-term data base.

Figure 3.



The number of seasons it takes to distinguish between the noise and the signal is not the same for each lake. Evaluation and interpretation of a long-term data base will indicate that the water quality of the lake has worsened, improved, or remained the same. In addition, different areas of a lake may show a different response. As more data is collected, prediction of current and future trends can be made. No matter what the outcome, this information is essential for the intelligent management of the lake.

There are also short-term uses for lay monitoring data. The examination of different stations in a lake can disclose the location of specific problems and corrective action can be initiated to handle the situation before it becomes more serious. On a lighter note, some associations post their weekly data for use in determining the best depths for finding fish!

It takes a considerable amount of effort as well as a deep concern for one's

lake to be a lay monitor in the **NH Lakes Lay Monitoring Program**. Many times a monitor has to brave inclement weather or heavy boat traffic to collect samples. Sometimes it even may seem that one week's data is just the same as the next. Yet every sampling provides important information on the variability of the lake.

We are pleased with the interest and commitment of our Lay Monitors and are proud that their work is what makes the **NH LLMP** the most extensive, and we believe, the best volunteer program of its kind.

Purpose and Scope of This Study

1994 was the sixth year that monitoring of Swain's Lake was undertaken by the **Freshwater Biology Group** and the Swain's Lake Association. The monitoring program was designed to continue adding data to the long-term data base established. Sampling emphasis was placed on two open water deep stations while supplementary **FBG** sampling of the deep sampling stations; Sites A and B, was undertaken on July 8 and August 19 to augment the volunteer monitoring data.

The primary purpose of this report is to discuss results of the 1994 monitoring season with emphasis on current conditions of Swain's Lake including the extent of eutrophication and the lake's susceptibility to increasing acid precipitation. This information is part of a large data base of historical and more recent data compiled and entered onto computer files for New Hampshire lakes that include New Hampshire Fish and Game surveys of the 1930's, the surveys conducted by the New Hampshire Water Supply and Pollution Control Commission and the

FBG surveys. However, care must be taken when comparing current results with early studies. Many complications arise due to methodological differences of the various analytical facilities and technological improvements in testing.

The General Scenario - 1994

1994 Climatic Summary

The winter of 1993-94 was one of the colder on record and included above average precipitation during the winter season. Snowfall was particularly plentiful in the months of January and March when major snowstorms made their way through New Hampshire. The accumulated snowpack resulted in considerable runoff in late March and Early April during the spring snowmelt. For those lakes which were monitored early enough, the winter conditions translated into lower alkalinities (buffering capacities) and lower pH levels in the tributary streams and in some lakes, when compared to results from a few years back; years with little snow pack. Thus, while many lakes had steady or even increasing buffering levels during dry winters (winters with below average snowfall), the heavy snowfall during the winter of 1993-94 indicates that acid rain should still be one of our concerns.

Below average rainfall was documented during the spring months of April and June while the month of May was wetter than normal. The month of July was off to a wet start with precipitation levels exceeding the norm by over one inch, followed by a dry month of August which demonstrated below average rainfall of over one inch, and once again a wetter than normal month in September. The 1994 precipitation levels (through September) were above normal while short-term dry spells were encountered; particularly in February, June and August. The summer months were also characterized by a number of localized rainstorms which passed

through New Hampshire. Thus, while the general precipitation scenario, described above, summarizes the 1994 precipitation data, the locality of daily precipitation events was highly variable and might not characterize the conditions around your lake.

The 1994 temperature patterns also had an effect on water quality. The below average temperatures in January, February and March maximized snowpack retention until late March when temperature exceeded 32° Fahrenheit and considerable watershed runoff occurred. The temperatures were more characteristic of the normal conditions in April and May while the month of June was characterized by above average temperatures. The above average temperatures in June resulted in the rapid surface water (epilimnetic) warming which is conducive to algal, aquatic plant and bacterial growth. Additional factors which stimulated the elevated algal, aquatic plant and bacterial growth included the influx of nutrients during summer storm events, greater sunlight penetration during clear days, lower lake levels during short-term dry spells, as well as, the mobilization of deep-water algal populations into the surface waters and increased growth rates during optimal conditions (discussed below). The above average temperatures, conducive to primary productivity, persisted through July but dipped to near average and below average levels in August and resulted in surface water cooling in our New Hampshire lakes which continued into the fall months.

1994 Water Quality Observations

Reduced Secchi Disk transparency readings, relative to 1993, were characteristic of most New Hampshire Lakes during the 1994 sampling season. Lakes were less clear due to a combination of factors that included increased dissolved color compounds (dissolved organic matter from the breakdown of vegetation and soils) washed in from surrounding wetland areas, higher algal growth (measured as chlorophyll *a*) in the surface waters, due to increased nutrient runoff and greater suspended sediment levels transported into the lake during storm events and increased bacterial growth. Dissolved water color is not indicative of water quality problems (although large increases in dissolved color sometimes follow large land clearing operations) but in some of our more pristine program lakes, it nevertheless has a large effect on water clarity changes. Likewise, elevated bacterial densities are not necessarily indicative of water quality problems as the majority of these organisms (heterotrophic, not pathogenic) are a natural component of even our cleanest lakes. However, these small organisms can have a profound effect on water quality as they can rapidly absorb and redirect light which will in turn diminish our Secchi Disk readings. If fecal contamination is suspected, future monitoring can include the collection of indicator bacteria data (i.e. *E. Coli*; the New Hampshire indicator bacteria).

As with dissolved color and nutrients, the wet spring brought a greater suspended sediment load to many of our streams and lakes during that period while short-term summer storm events resulted in additional sedimentation. If decreased clarity was not the result of

increased dissolved color or chlorophyll *a* levels than it was likely due to increased suspended sediment by default. To find out how these water quality indicators inter-relate for Swain's Lake, compare the Secchi Disk, chlorophyll *a* and dissolved color graphs enclosed in this report (see figures 6-11). Note whether changes in clarity (secchi disk depth) correspond to chlorophyll *a* or dissolved color concentration changes or whether it is a combination of the two. If neither seem to exhibit a consistent effect, then suspended sediment likely plays an important role in your lake's clarity.

Several lakes experienced "algal blooms" during the 1994 sampling season. "Algal blooms" are often "green water events" associated with decreases in water clarity due to their ability to absorb and scatter light within the water column, but can also accumulate near the lake bottom in shallow areas as "mats" or on the water surface as "scums" and "clouds". All types of "algal blooms" were observed in several participating LLMP lakes in 1994. The occasional formation of certain "algal blooms" are naturally occurring phenomenon and are not necessarily associated with changes in lake productivity. Increases in the occurrence of "bloom" conditions can be a sign of eutrophication (the "greening" of a lake). Algal blooms of varied extent typically occur even in our most pristine lakes late in the fall and early in the spring as a result of lake mixing, which resuspends nutrients, at those times.

In many lakes, particularly those within the Lakes Region of New Hampshire, cotton-candy like "clouds" of the nuisance green filamentous algae, *Mougeotia*, or a related species formed within the weed beds and then drifted freely into shallow areas around the lake. These algae often take advantage

of nutrients that leak from particularly active submerged weeds or from bottom areas that have been disturbed by weed removal or other activities.

For some lakes, weather conditions became conducive to the formation of "blooms" of other algae species during the summer months when the water temperatures were above average. Unlike 1993, when the algal blooms were short-term events (spanning less than a week), the blooms persisted for greater than a month in a handful of sampled lakes. In those lakes which experienced long-term algal blooms the types of algae tended to be of the nuisance blue-green bacterial variety (formerly referred to as blue-green algae) and included such nuisance forms as *Anabaena*, *Lyngbya* and *Merismopedia*.

In other lakes, metalimnetic algae, algae which tend to grow in a thin layer along the thermocline gradient in a lake's middle depths, sometimes migrate up towards the lake surface causing a "bloom" event. If these algae are predominantly "nuisance" forms, like certain green or blue-green algae, they can be an early indication nutrient loading. The **LLMP** will continue to monitor "bloom" phenomenon in 1995 as it can be a sign of the changing land use practices and impacts within the lake watershed that can result in a long-term increase in lake productivity. Future monitoring will continue to monitor the frequency of algal blooms in our New Hampshire lakes' and discern whether or not they are signs of short-term perturbations in water quality, the "noise" within the true long-term signal, induced by the weather conditions of this past summer.

SWAIN'S LAKE

1994 NON-TECHNICAL SUMMARY

Weekly sampling of Swain's Lake was undertaken by the volunteer monitors from May 22 through September 19, 1994 while more in-depth sampling of Swain's Lake was performed by the FBG on July 8 and August 19, 1994 (refer to appendix A). The following section summarizes the 1994 findings and when applicable incorporates historical data into the interpretation.

1) The Secchi Disk transparency (a measure of water clarity) measured by the Swain's Lake volunteer monitors was low to moderate and suggests moderately to highly productive conditions. The 1994 Secchi Disk transparency averaged 2.3 meters (7.5 feet) with a range of 1.8 to 2.8 meters at Site A and averaged 2.6 meters (8.5 feet) with a range of 2.0 to 3.5 meters at Site B. Transparency values greater than 4 meters are typical of a clear, unproductive, lake while transparency values less than 2.5 meters are generally an indication of a highly productive lake. Secchi Disk readings between 2.5 and 4.0 meters are considered indicative of a moderately productive lake.

The 1994 seasonal average Secchi Disk transparency decreased for the fourth consecutive year at both deep sampling stations: Sites A and B (figures 14 and 16) and established new seasonal average Secchi Disk lows at both sites. New Secchi Disk transparency lows of 1.8 meters (September 11) and 2.0 meters (August 15 and 21) were also documented at Sites A and B, respectively, during the summer months.

2) Chlorophyll *a* concentrations (a measure of microscopic plant abundance) collected by the Swain's Lake volunteer monitors and measured by the FBG were moderate to high in 1994. The seasonal chlorophyll *a* concentration averaged 17.8 milligrams per cubic meter (17.8 mg m^{-3} equivalent to 17.8 parts chlorophyll *a* per billion parts water) at Site A and averaged 14.5 mg m^{-3} at Site B. Chlorophyll *a* concentrations below 3 mg m^{-3} are common to an unproductive lake while chlorophyll *a* concentrations above 7 mg m^{-3} are common to a productive lake. Chlorophyll *a* concentrations between 3 mg m^{-3} and 7 mg m^{-3} are considered characteristic of a moderately productive lake.

The 1994 Swain's Lake seasonal chlorophyll *a* concentrations were typical of a highly productive lake and remained within the range considered indicative of moderately to highly productive conditions the entire sampling season. As in 1993, limited rainfall during the summer months (particularly the "drought" conditions in June and July) and the high water temperatures were conducive to the blue-green algal populations known to "bloom" in Swain's Lake. While a number of localized rainstorms made their way through New Hampshire in June and July, the majority missed Swain's Lake during that span and resulted in atypically low precipitation levels (personal communication). Comparison of the sampling stations (Sites A and B) in 1994 indicate a higher level of lake productivity at Site

A relative to Site B which is consistent with the conditions observed in previous years of monitoring (see figures 12, 15 and 17).

3) Dissolved lakewater color levels averaged for the season, 46.5 platinate color units (ptu), were moderate and greater than the seasonal average of 25.7 ptu for **LLMP** lakes. Dissolved, color, or true color as it is sometimes called, is indicative of dissolved organic carbon levels in the water (a by-product of microbial decomposition). Small increases in water color from the natural breakdown of plant materials in and around a lake are not considered to be detrimental to water quality. However, increased color can lower water transparency, and hence, change the public perception of water quality. Large amounts of dissolved color might occur naturally but can also occur during deforestation and development within the watershed. High color levels can actually mask the ability of the Secchi Disk transparency to predict chlorophyll levels. The Swain's Lake seasonal average dissolved color concentration increased at both deep sampling stations in 1994 and set a new seasonal average dissolved color high of 59.9 ptu at Site A and also included a new dissolved color high of 371.1 documented at Site A on September 4, 1994.

4) Total phosphorus (generally considered the limiting nutrient for plant growth in freshwater systems) concentrations, collected in the surface waters, were low to moderate when sampled by the **FBG** on July 8 and August 19, 1994 with a range of 13.6 to 16.9 parts per billion (ppb). Total phosphorus concentrations increased towards the lakebottom and reached 62.4 ppb at 6.0 meters depth on August 19, 1994 (Site A). Total phosphorus concentrations near the lakebottom were well in excess of 15 ppb which is commonly

considered sufficient to cause an algal bloom.

5) The 1994 surface Swain's Lake pH (range: 6.3 to 6.4), measured by the **FBG**, remained within the optimum range for most aquatic organisms. However, the alkalinity (a measurement of the lake's resistance to acidification) of the lake was low, 1.8 units, and is considered extremely vulnerable to acidification based on the state standard. Historical sampling of Swain's Lake by the New Hampshire Fish and Game Department (August 19, 1937) documented an alkalinity level of 7 units (parts per million) while latter sampling by the New Hampshire Department of Environmental Service (July 15, 1976 and September 4, 1987) documented a decrease in the alkalinity concentrations with surface water alkalinities between 3.0 and 5.0 units in 1976 and surface water alkalinities between 2.3 and 2.4 units in 1987. Data collected by the volunteer **LLMP** monitors between 1989 and 1994 have documented a continued trend of decreasing alkalinity over that period. However, methodological differences by the aforementioned agencies make direct comparisons impossible and one must therefore interpret the data with caution.

6) The specific conductivity of the Swain's Lake deep sites was low and ranged from 38.8 to 55.2 micro-Siemans per centimeter at Site A and from 38.9 to 55.7 micro-Siemans per centimeter at Site B. Specific conductivity increased towards the lakebottom of both sampling stations and suggests an accumulation of nutrients near the lakebottom. High conductivity values can indicate the presence of septic leachate, excessive fertilizer use or deicing road salt runoff.

7) Temperature profiles collected by the volunteer monitors and the **FBG**

indicate Swain's Lake became stratified into two distinct thermal layers when the weather was calm; an upper warm water layer (epilimnion) overlying a layer of rapid temperature change (thermocline). The formation of temperature stratification limits water circulation and can favor anoxic conditions in the deeper waters (thermocline). Dissolved oxygen data collected by the **FBG** on July 8, 1994 indicate the oxygen concentrations remained above the concentration of 3 milligrams per liter (the minimum concentration required for the successful growth and reproduction of most warmwater fish) only down to about 4 meters at Both Sites: A and B (figures 18 and 19). Latter dissolved oxygen sampling (August 19) indicated the dissolved oxygen concentrations became reduced below 3 milligrams per liter at about 4 meters at Site A and at about 5.5 meters at Site B (figures 18 and 19). As dissolved oxygen concentrations become depleted, chemical reactions convert previously insoluble nutrients into a soluble form. The nutrients can then be utilized by layering mid-lake algal cells or utilized by surface forms when thermal stratification is disrupted. Temperature profiles collected by the volunteer monitors indicate Swain's Lake was stratified during most of the summer sampling season and was thus susceptible to internal nutrient loading (nutrients released from the lake sediments). Total phosphorus data confirm the presence of higher phosphorus concentrations near the lakebottom and are indicative of internal nutrient loading.

8) Based on the 1994 and historical data, Swain's Lake would be considered a highly productive lake. 1994 was an exceptionally poor year in terms of water quality for Swain's Lake. Data collected over the past six years (1989-1994) indicate the productivity of the lake has gradually increased as exem-

plified by the decreasing Secchi Disk readings and increasing chlorophyll *a* concentrations over that period (figures 14 through 17). In a moderately stained (due to color dissolved in the water) lake such as Swain's, the dissolved color can often be attributed to changes in the Secchi Disk depth. However, between 1989 and 1993, the seasonal average dissolved color concentrations actually decreased and thus imparted less of a negative impact (i.e. lower water clarities) on the Secchi Disk readings, thus leaving either an increase in chlorophyll *a* concentrations or an increase in the suspended sediment load as the culprit. Both the dissolved color and chlorophyll *a* concentrations increased in 1994 and each variable likely had a negative impact on the Secchi Disk transparency.

While suspended sediment levels were not quantified, the dry summers of the 1990's minimized watershed runoff and thus limited sediment loading over that period, although motorboat activity can result in shoreline erosion and the resuspension of materials off the lake-bottom during active periods of motorboat use. Elevated seasonal chlorophyll *a* concentrations during the 1994 sampling season suggest the elevated chlorophyll *a* (algal) concentrations had a large role in the decreasing Secchi Disk depths. The chlorophyll *a* concentrations in Swain's Lake have typically fallen within the range of a moderately productive lake but have shown signs of a higher level of productivity during the six years of monitoring. The 1993 and 1994 chlorophyll *a* samples actually exhibited concentrations more typical of a highly productive lake through most of the sampling season.

In addition to the surface water chlorophyll *a* samples, the **FBG** and volunteer monitors have been collecting mid-lake chlorophyll *a* samples to determine whether or not a mid-lake algal populations exists. Based on the current and historical data collected by the vol-

unteers and **FBG**, Swain's Lake supports a mid-lake algal population which is not apparent from surface sampling alone. The occurrence of such populations are likely contributing to the decreased water transparencies and should thus be monitored in the future. These mid-lake algal populations are often an indication of internal nutrient loading (nutrient being released from the sediments). With the low dissolved oxygen concentrations observed during periods of thermal stratification, phosphorus is released from the sediments and can support these mid-lake algal layers. It is therefore recommended that phosphorus sampling is incorporated into the future sampling scheme to assess the degree of this phenomenon. Future sampling should also focus on locating potential problem areas in the watershed.

To minimize future degradation to the lake, it is important to follow the best management practices in regards to current and future land use in the watershed. Shoreline areas and the surrounding wetlands should be protected from modification and degradation. A natural vegetative buffer strip should be fostered around the lake shore and around the streams which will trap sediments and nutrients before they can enter the lake. The use of fertilizers, pesticides and herbicides should be avoided on land that is close to the shore or bordering streams that feed the lake. When construction must be done, the proper soil conservation procedures and practices should be followed. Proper maintenance of septic systems is important to maximize their effectiveness and minimize nutrient seepage into the lake. It is important to note that all activities within the Swain's Lake watershed can have a significant impact on the condition of the lake.

volunteer monitors of Swain's Lake are doing an excellent job of measuring the water quality at both deep sampling stations.

9) Comparisons between the **FBG** and volunteer monitor data indicate the

COMMENTS AND RECOMMENDATIONS

1) We recommend that each participating association, including the Swain's Lake Association, continue to develop its data base on lake water quality through continuation of the long-term monitoring program. The data base will provide information on the short and long-term cyclic variability that occurs in the lake and will eventually enable more reliable predictions of water quality trends.

2) Sampling by the **FBG** and volunteer monitors has documented the presence of a mid-lake algal population in Swain's Lake. Since these mid-lake algal populations can affect the Secchi Disk readings and can be an early indication of increasing lake productivity, yet are not apparent from surface sampling alone, we recommend continued monitoring of the algal populations. We suggest weekly mid-lake algal sampling beginning in June and continuing through August to monitor this phenomenon at both deep sampling stations (Sites A and B). The **FBG** will give a discount for the collection of mid-lake algal samples to help minimize the association's costs. Contact the **LLMP** coordinator for further information.

3) We suggest collecting dissolved oxygen data during the 1995 sampling season. Dissolved oxygen sampling has indicated that the deeper waters become depleted of oxygen during periods of thermal stratification. Oxygen depletion can in turn result in elevated nutrient concentrations (released from the bottom sediments) that can stimulate algal growth and reduce the Secchi Disk depth. Depleted dissolved oxygen concentration in the deeper waters also re-

strict fish populations to the upper waters and under unfavorable surface water temperatures can result in fish kills. Monitoring during the summer months would help determine the extent of the oxygen depletion. Dissolved oxygen sampling kits are available on loan from the UNH County Cooperative Extension offices or can be borrowed from the Cooperative Extension office located on the UNH campus. Contact the **LLMP** coordinator for further information.

4) Due to the shallowness of Swain's Lake, the potential exists for the resuspension of materials off the lakebottom due to motorboat use. If interested, a boat effect study could be initiated on the lake. All that would be required is sampling in the morning and then the same day late in the afternoon on a "quiet day" followed by the same sampling approach on a day of heavy boat traffic. While only transparency measurements are necessary, a discount for sample processing will be offered to minimize the costs of additional sampling. Contact the **LLMP** for further information.

5) Changing land use within the Swain's Lake watershed, the surrounding land that drains into the lake, can accelerate the natural aging process. A typical lake fills in and becomes more productive on a geological time frame (thousands of years), however, this process can be accelerated and occur in tens of years when development, agriculture and other landscape changes occur that do not incorporate best management practices (i.e. maintaining vegetative buffer strips along the shoreline, minimizing fertilizer and pesticide

applications, installing proper erosion control structures, etc.) that are set up to minimize water quality impacts. We invite interested persons to take part in a new assessment manual, produced jointly by the **UNH LLMP** and the U S Natural Resource Conservation Service (**US NRCS**), which provides the layperson with a systematic method for recognizing and evaluating erosion, sedimentation and related non-point source (NPS) pollutant problems in New Hampshire watersheds. With the current trend of increased development and land sales in New Hampshire such a survey is highly recommended. Contact the **LLMP** coordinator for further information.

DISCUSSION OF LAKE MONITORING MEASUREMENTS

The section below details the important concepts involved for the various testing procedures used in the **New Hampshire Lakes Lay Monitoring Program**. Where appropriate, summary statistics of 1994 results from all participating lakes are included. Certain tests or sampling performed at the time of the optional **Freshwater Biology Group** field trip are indicated by an asterisk (*).

Thermal Stratification in the Deep Water Sites

Lakes in New Hampshire display distinct patterns of temperature stratification, that develop as the summer months progress, where a layer of warmer water (the **epilimnion**) overlies a deeper layer of cold water (**hypolimnion**). The layer that separates the two regions characterized by a sharp drop in temperature with depth is called the **thermocline** or **metalimnion** (figure 4). Some shallow lakes may be continually mixed by wind action and will never stratify. Other lakes may only contain a developed epilimnion and metalimnion. Swain's Lake became stratified into two distinct thermal layers (an epilimnion and thermocline) during the summer months.

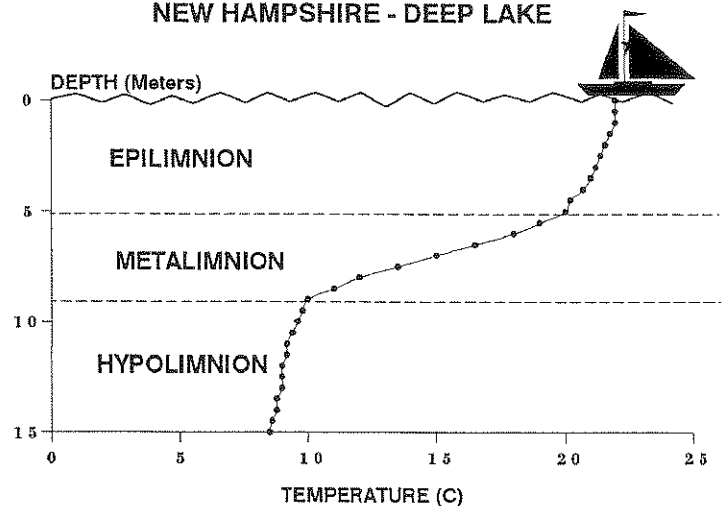
Water Transparency

Secchi Disk depth is a measure of the water transparency. The deeper the depth of secchi disk disappearance, the

more transparent the lake water; light penetrates deeper if there is little dissolved and/or particulate matter (which includes both living and non-living particles) to absorb and scatter it.

Figure 4.

TYPICAL TEMPERATURE CONDITIONS : SUMMER
NEW HAMPSHIRE - DEEP LAKE



In the shallow areas of many lakes, the secchi disk will hit bottom before it is able to disappear from view (what is referred to as a "Bottom Out" condition). Thus, Secchi disk measurements are generally taken over the deepest sites of a lake. Transparency values greater than 4 meters are typical of clear, less productive lakes while transparency values less than 2.5 meters are generally an indication of highly productive lakes. Water transparency values between 2.5 meters and 4 meters are generally considered in-

dicative of moderately productive lakes. In 1994 the average transparency for lakes participating in the **NH LLMP** was 5.6 meters with a range of 0.3 to 10.7 meters.

The Swain's Lake Secchi Disk transparencies have gradually decreased over the six years of participation in the **NH LLMP** (table 1 and figures 14 and 16). The seasonal average Secchi Disk readings have decreased from 3.6 meters in 1989 to 2.3 meters in 1994 at Site A and decreased from 4.1 meters in 1989 to 2.6 meters in 1994 at Site B.

Table 1. Historical Lay Monitor Secchi Disk Data comparison of Swain's Lake.

Site	Year	Trans- parency (m) Minimum	Trans- parency (m) Average	Trans- parency (m) Maximum	Sample Size
A	1989	2.5	3.6	4.6	13
A	1990	2.5	3.7	4.8	17
A	1991	2.5	3.3	3.8	14
A	1992	2.5	3.3	4.0	8
A	1993	2.0	2.8	3.5	10
A	1994	1.8	2.3	2.8	16
B	1989	3.1	4.1	5.7	13
B	1990	3.1	4.3	5.8	18
B	1991	3.0	4.0	5.5	14
B	1992	3.0	3.7	4.7	10
B	1993	2.5	3.0	3.5	11
B	1994	2.0	2.6	3.5	15

Chlorophyll *a*

The chlorophyll *a* concentration is a measurement of the standing crop of phytoplankton and is often used to classify lakes into categories of productivity called trophic states. **Eutrophic** lakes are highly productive with large concentrations of algae and aquatic plants due to nutrient enrichment. Characteristics include accumulated organic matter in the lake basin and lower dissolved oxygen in the bottom waters.

Summer chlorophyll *a* concentrations average above 7 mg m⁻³ (7 milligrams per cubic meter; 7 parts per billion). **Oligotrophic** lakes have low productivity and low nutrient levels and average summer chlorophyll *a* concentrations are generally less than 3 mg m⁻³. These lakes generally have cleaner bottoms and high dissolved oxygen levels throughout. **Mesotrophic** lakes are intermediate in productivity with concentrations of chlorophyll *a* generally between 3 mg m⁻³ and 7 mg m⁻³. In 1994, the average chlorophyll *a* concentration for lakes participating in the **NH LLMP** was 3.3 mg m⁻³ with a range of 0.4 to 58.1 mg m⁻³.

The 1994 Swain's Lake chlorophyll *a* measurements fall within the range typical of a highly productive, eutrophic, lake (table 2 and figures 15 and 17). While chlorophyll *a* data collected between 1989 and 1992 were more characteristic of moderately productive conditions, the 1993 and 1994 data fall well within the range considered indicative of a highly productive lake.

Table 2. Historical Lay Monitor Chlorophyll *a* Data comparison of Swain's Lake.

Site	Year	Chl <i>a</i> (ppb) Minimum	Chl <i>a</i> (ppb) Average	Chl <i>a</i> (ppb) Maximum	Sample Size
A	1989	2.5	6.6	18.8	13
A	1990	2.1	8.0	42.1	18
A	1991	2.2	13.4	133.7	14
A	1992	2.4	6.3	18.5	8
A	1993	6.0	11.6	31.9	10
A	1994	4.6	17.8	58.1	16
B	1989	2.4	5.5	13.7	13
B	1990	2.6	5.0	7.9	18
B	1991	2.0	3.5	5.1	14
B	1992	2.6	3.6	4.8	10
B	1993	4.3	11.1	43.7	11
B	1994	4.0	14.5	40.5	14

Testing is sometimes done to check for **metalimnetic algal popula-**

tions, algae that layer out at the thermocline and generally go undetected if only epilimnetic (point or integrated) sampling is undertaken. Chlorophyll concentrations of a water sample collected in the thermocline is compared to the integrated epilimnetic sample. Greater chlorophyll levels of the point sample, in conjunction with microscopic examination of the samples (see Phytoplankton section below), confirm the presence of such a population of algae. These populations should be monitored as they may be an indication of increased nutrient loading into the lake.

FBG sampling conducted on July 8, 1994 and August 19, 1994 documented a stratifying mid-lake algal layer at both deep sampling stations: Sites A and B (refer to Appendix A). The mid-lake chlorophyll *a* concentration peaked at 101.4 mg m⁻³ (6.0 meters) at Site A on August 19, 1994 and suggests elevated algal densities near the lake-bottom. Higher algal densities near the lakebottom were confirmed by the FBG and are discussed latter in the report.

Dissolved Color

The dissolved color of lakes is generally due to dissolved organic matter from **humic substances**, which are naturally-occurring polyphenolic compounds leached from decayed vegetation. Highly colored or "stained" lakes have a "tea" color. Such substances generally do not threaten water quality except as they diminish sunlight penetration into deep waters. Increases in dissolved watercolor can be an indication of increased development within the watershed as many land clearing activities (construction, deforestation, and the resulting increased run-off) add additional organic material to lakes. Natural fluctuations of dissolved color occur when

storm events increase drainage from wetlands areas within the watershed. As suspended sediment is a difficult and expensive test to undertake, both dissolved color and chlorophyll information is important when interpreting the secchi disk transparency

Dissolved color is measured on a comparative scale that uses standard chloroplatinate dyes and is designated as a color unit or ptu. Lakes with color below 10 ptu are very clear, 10 to 20 ptu are slightly colored, 20 to 40 ptu are lightly tea colored, 40 to 80 ptu are tea colored and greater than 80 ptu indicates highly colored waters. Generally the majority of New Hampshire lakes have color between 20 to 30 ptu. In 1994 the average dissolved color for participating NH LLMP lakes was 25.7 ptu with a range of 2.6 to 371.1 ptu. Refer to table 3 for a summary of 1994 Swain's Lake dissolved color data.

Table 3. 1994 Lay Monitor Dissolved Color Data comparison of Swain's Lake.

Site	Color (ptu) Minimum	Color (ptu) Average	Color (ptu) Maximum	Sample Size
A	26.6	59.9	371.1	17
B	24.1	31.3	39.5	15

Total Phosphorus

Of the two "nutrients" most important to the growth of aquatic plants, nitrogen and phosphorus, it is generally observed that phosphorus is the more limiting to plant growth, and therefore the more important to monitor and control. Phosphorus is generally present in lower concentrations, and its sources arise primarily through human related activity in a watershed. Nitrogen can be fixed from the atmosphere by many bloom-forming blue-green bacteria, and

thus it is difficult to control. The total phosphorus includes all dissolved phosphorus as well as phosphorus contained in or adhered to suspended particulates such as sediment and plankton. As little as 15 parts per billion of phosphorus in a lake can cause an algal bloom.

Generally, in the more pristine lakes, phosphorus values are higher after spring melt when the lake receives the majority of runoff from its surrounding watershed. The nutrient is used by the algae and plants which in turn die and sink to the lake bottom causing phosphorus to decrease as the summer progresses. Lakes with nutrient loading from human activities and sources (Agriculture, Sediment Erosion, Septic Systems, etc.) will show greater concentrations of nutrients as the summer progresses or after major storm events. Circulation of nutrients from the bottom waters of more productive lakes in late fall can result in algal blooms.

Total phosphorus concentrations, measured by the **FBG**, indicate the surface water Swain's Lake phosphorus levels bordered the concentration of 15 ppb considered sufficient to cause an algal bloom and ranged from 13.6 to 16.9 ppb on July 8 and August 19, 1994. Higher total phosphorus concentrations were documented near the lakebottom and peaked at the concentration of 62.4 ppb (6.0 meters) at Site A, August 19, 1994.

pH *

The pH is a way of expressing the acidic level of lake water, and is generally measured with an electrical probe sensitive to hydrogen ion activity. The pH scale has a range of 1 (very acidic) to 14 (very "basic" or alkaline) and is logarithmic (i.e.: changes in 1 pH unit reflect a ten times difference in hy-

drogen ion concentration). Most aquatic organisms tolerate a limited range of pH and most fish species require a pH of 5.5 or higher for successful growth and reproduction.

Surface pH levels, measured by the **FBG** ranged from 6.3 to 6.4 pH units in Swain's Lake on July 8, 1994 and August 19, 1994.

Alkalinity

Alkalinity is a measure of the buffering capacity of the lake water. The higher the value the more acid that can be neutralized. Typically lakes in New Hampshire have low alkalinities due to the absence of carbonates and other natural buffering minerals in the bedrock and soils of lake watersheds.

Decreasing alkalinity over a period of a few years can have serious effects on the lake ecosystem. In a study on an experimental acidified lake in Canada by Schindler, gradual lowering of the pH from 6.8 to 5.0 in an 8-year period resulted in the disappearance of some aquatic species, an increase in nuisance species of algae and a decline in the condition and reproduction rate of fish. During the first year of Schindler's study the pH remained unchanged while the alkalinity declined to 20 percent of the pre-treatment value. The decline in alkalinity was sufficient to trigger the disappearance of zooplankton species, which in turn caused a decline in the "condition" of fish species that fed on the zooplankton.

The analysis of alkalinity employed by the **Freshwater Biology Group** includes use of a dilute titrant allowing an order of magnitude greater sensitivity and precision than the standard method. Two endpoints are recorded during each analysis. The first endpoint (gray color of dye; pH endpoint

of 5.1) approximates low level alkalinity values, while the second endpoint (pink dye color; pH endpoint of 4.6) approximates the alkalinity values recorded historically, such as NH Fish and Game data, with the methyl-orange endpoint method.

The average alkalinity of lakes throughout New Hampshire is low, approximately 9 mg per liter (calcium carbonate alkalinity), while the average alkalinity of the lakes studied by the **Freshwater Biology Group** in the **NH LLMP** is approximately 6.3 mg per liter. When alkalinity falls below 2 mg per liter the pH of waters can greatly fluctuate. Alkalinity levels are most critical in the spring when acid loadings from snowmelt and run-off are high, and many aquatic species are in their early, and most susceptible, stages of their life cycle.

The alkalinity of Swain's Lake is low, with a seasonal average of 1.8 units. According to the criteria employed by the New Hampshire Department of Environmental Services, Swain's Lake is considered extremely vulnerable to acid precipitation. Past monitoring by the New Hampshire Fish and Game Department and the NH Department of Environmental Services, and more recent monitoring by the **NH LLMP** indicates a trend of decreasing alkalinities in Swain's Lake. Future monitoring of Swain's Lake should continue to focus on spring sampling, when the lake is most susceptible to acid inputs, and continue through the summer sampling season to detect short term fluctuations in the alkalinity concentrations following storm events.

Specific Conductivity *

The specific conductance of a water sample indicates concentrations of

dissolved salts. Leaking septic systems and deicing salt runoff from highways can cause high conductivity values. Fertilizers and other pollutants can also increase the conductivity of the water. Conductivity is measured in micromhos (the opposite of the measurement of resistance **ohms**) per centimeter, more commonly referred to as micro-Siemans.

The specific conductivity levels documented at the Swain's Lake deep sampling stations remained low (range: 38.8 to 55.7 micro-Siemans per centimeter) but increased towards the lakebottom on July 8, 1994 and August 19, 1994. Higher conductivity readings near the lakebottom are often associated with anoxic conditions which were characteristic of Swain's Lake on both sampling dates. Under anoxic conditions materials become soluble, including the nutrient phosphorus, and increase the conductance of the lakewater.

Dissolved Oxygen and Free Carbon Dioxide *

Oxygen is an essential component for the survival of aquatic life. Submergent plants and algae take in free carbon dioxide and create oxygen through **photosynthesis** by day. **Respiration** by both animals and plants uses up oxygen continually and creates **carbon dioxide**. Dissolved oxygen profiles determine the extent of declining oxygen concentrations in the lower waters. High carbon dioxide values are indicative of low oxygen conditions and accumulating organic matter. For both gases, as the temperature of the water decreases, more gas can be dissolved in the water.

The typical pattern of clear, unproductive lakes is a slight decline in hypolimnetic oxygen as the summer progresses. Oxygen in the lower waters

is important for maintaining a fit, reproducing, cold water fishery. Trout and salmon generally require oxygen concentrations above 5 mg per liter (parts per million) in the cool deep waters. On the other hand, carp and catfish can survive very low oxygen conditions. Oxygen above the lake bottom is important in limiting the release of nutrients from the sediments and minimizing the collection of undecomposed organic matter.

Bacteria, fungi and other **decomposers** in the bottom waters break down organic matter originating from the watershed or generated by the lake. This process uses up oxygen and produces carbon dioxide. In lakes where organic matter accumulation is high, oxygen depletion can occur. In highly stratified eutrophic lakes the entire hypolimnion can remain unoxygenated or **anaerobic** until fall mixing occurs.

The oxygen peaks occurring at surface and mid-lake depths during the day are quite common in many lakes. These characteristic **heterograde oxygen curves** are the result of the large amounts of oxygen, the by-product of photosynthesis, collecting in regions of high algal concentrations. If the peak occurs in the thermocline of the lake, metalimnetic algal populations (discussed above) may be present.

The dissolved oxygen concentrations, measured at the Swain's Lake deep sampling stations; Sites A and B, were depleted (dissolved oxygen concentration less than 1 milligram per liter) in the thermocline when measured by the **FBG** on July 8, 1994 and August 19, 1994 (figures 18 and 19). The anoxic conditions are indicative of accumulating organic matter in the deep sampling stations which supports a population of microbial decomposers along the lake-bottom. High carbon dioxide concentra-

tions (in excess of 22 milligrams per liter) near the lakebottom are a further indication of a high level of microbial decomposition along the lakebottom.

Underwater Light *

Underwater light available to photosynthetic organisms is measured with an **underwater photometer** which is much like the light meter of a camera (only waterproofed !). The **photic zone** of a lake is the volume of water capable of supporting photosynthesis. It is generally considered to be delineated by the water's surface and the level where light is reduced, by the absorption and scattering properties of the lake water, to one percent of the surface intensity. The one percent depth is sometimes termed the **compensation depth**. Knowledge of light penetration is important when considering lake productivity and in studies of submerged vegetation. Discontinuity (abrupt changes in the slope) of the profiles could be due to metalimnetic layering of algae or other particulates (discussed above). The underwater photometer allows the investigator to measure light at depths below the Secchi disk depth to supplement the transparency information.

Indicator Bacteria *

Coliform bacteria in water indicate the possibility of fecal contamination. Although they are usually considered harmless to humans, they are much easier to test for than harmful pathogenic enteric bacteria (*Salmonella*, *Shigella* etc.) and viruses that may be present in fecal material. **Total coliform** includes all coliform bacteria which arise from the gut of animals or from vegetative materials.

Fecal coliform are those specific organisms that inhabit the gut of warm blooded animals. Another indicator organism **Fecal streptococcus** (sometimes referred to as **enterococcus**) also can be monitored. The ratio of fecal coliform to fecal strep may be useful in suggesting the type of animal source responsible for the contamination. In 1991, the State of New Hampshire changed the indicator organism of preference to E. Coli which is a specific type of fecal coliform bacteria thought to be a better indicator of human contamination. The new state standard requires Class A bathing waters to be under 88 organisms per 100 milliliters of lakewater.

Ducks and geese are often a common cause of high concentrations of coliform at specific lake sites. While waterfowl are important components to the natural and aesthetic qualities of lakes that we all enjoy, it is poor management practice to encourage these birds by feeding them. The lake and surrounding area provides enough healthy and natural food for the birds and feeding them stale bread or crackers does nothing more than import additional nutrients into the lake and allows for increased plant growth. As birds also are a host to the parasite that causes "swimmers itch", waterfowl roosting areas offer a greater chance for infestation to occur. Thus while leaving offerings for our feathered friends is enticing, the results can prove to be detrimental to the lake system and to human health.

Phytoplankton *

The planktonic community includes microbial organisms that represent diverse life forms, containing photosynthetic as well as non-photosynthetic types, and including bac-

teria, algae, crustaceans and insect larvae (the zooplankton are discussed below in a separate section). Because planktonic algae or "phytoplankton" tend to undergo rapid seasonal cycles on a time scale of days and weeks, the levels of populations found should be considered to be most representative of the time of collection and not necessarily of other times during the ice-free season, especially the early spring and late fall periods.

The composition and concentration of phytoplankton can be indicative of the trophic status of a lake. Seasonal patterns do occur and must be considered. For example **diatoms**, tend to be most abundant in April-June and October-November, in the surface or epilimnetic layers of New Hampshire lakes. As the summer progresses, the dominant types might shift to **green algae** or **golden algae**. By late season **Blue-green bacteria** generally dominate. In nutrient rich lakes, nuisance green algae and/or bluegreen bacteria might dominate continually. After fall mixing diatoms might again be found to bloom.

Swain's Lake phytoplankton densities were high on both the July 8, 1994 (1944 to 2661 algal units per milliliter) and the August 19, 1994 (4318 to 4509 algal units per milliliter) sampling dates. The algal densities and types of algae present are common of moderately to highly productive lakes (figures 20 and 21). Both deep sampling stations were dominated by the green flagellated algae, *Chlamydomonas*, on July 8 while the dominant algae on the latter sampling date was the filamentous blue-green bacteria, *Lyngbya*, which has dominated Swain's Lake in previous years.

Higher mid-lake algal densities were documented in the metalimnion of Swain's Lake (range: 5992 to 7355 algal

units per milliliter) on the August 19 sampling date and were dominated by the blue-green bacteria, *Lyngbya*. The higher mid-lake algal densities correspond to elevated mid-lake chlorophyll *a* concentrations previously discussed.

Zooplankton *

There are three groups of zooplankton that are generally prevalent in lakes: the **protozoa**, **rotifers** and **crustaceans**. Most research has been devoted to the last two groups although protozoa may be found in substantial amounts. Of the rotifers and the crustaceans, time and budgetary constraints usually make it necessary to sample only the larger zooplankton (macrozooplankton; larger than 80 or 150 microns; 1 million microns make up a meter). Thus, zooplankton analysis is generally restricted only to the larger crustaceans. Crustacean zooplankton are very sensitive to pollutants and are commonly used to indicate the presence of toxic substances in water. The crustaceans can be divided into two groups, the **cladocerans** (which include the "water fleas") and the **copepods**.

Macrozooplankton are an important component in the lake system. The filter feeding of the herbivorous ("grazing") species may control the population size of selected species of phytoplankton. The larger zooplankton can be an important food source for juvenile and adult planktivorous fish. All zooplankton play a part in the recycling of nutrients within the lake.

As discussed above for phytoplankton, zooplankton undergo seasonal population cycles and the results discussed below are most representative of the collection dates and not necessarily of other times during the ice-free season,

especially during the early spring and late fall.

Macro-zooplankton densities measured by the **FBG** in Swain's Lake, were low to moderate on July 8, 1994 (3.1 to 6.9 animals per liter) and were high on August 19, 1994 (24.9 to 44.2 animals per liter). Both deep sampling sites; A and B, were dominated by the *Cyclopoid* copepods on July 8 while the cladoceran, *Bosmina*, was the sub-dominant zooplanktonic form (figure 22). The *Cyclopoids* remained dominant on August 19 while the sub-dominant zooplanktonic form shifted to the cladoceran, *Eubosmina*. The macro-zooplanktonic community was dominated by smaller zooplankton forms and might reflect a high predatory fish population which selectively preys on the larger zooplanktonic forms such as the water flea, *Daphnia*. Continuing research at Dartmouth College is addressing the use of zooplankton as indicators of lake productivity. Future **FBG** reporting will incorporate the results of this study as they become available.

Zebra Mussels

Zebra mussels (*Dreissena polymorpha*) are non-native, freshwater mollusks. Their shells are marked by varying patterns of alternating dark and light bands and they are typically less than two inches long. The veligers (larval form) are free swimming, nearly invisible, and profuse. The adults secrete strong byssal threads by which they attach and reattach themselves to a variety of surfaces. These threads allow them to colonize quickly and reach densities of 100,000 or more mussels per square yard. The mussels have an average lifespan of 3.5 to 5 years.

Zebra mussels originated in the drainage basins of the Black, Caspian,

and Aral seas of eastern Europe and have been in western Europe freshwaters since the 1700s. Since first being introduced to North America in 1986, zebra mussels have dramatically altered the balance of freshwater systems and fisheries. These small water dwelling animals have also caused millions of dollars in expenses for industrial water users, drinking water facilities, commercial and recreational boaters, farmers, and other groups and organizations in Canada and the Great Lakes region.

The range occupied by these unwelcome visitors has expanded and continues to grow rapidly. In North America, sightings have been recorded as far north as the Saint Lawrence River near Quebec, as far east as the lower portion of the Hudson River, as far south as the Mississippi River near Vicksburg, and as far west as the Arkansas River in Oklahoma.

In 1993, zebra mussel sightings were confirmed in New England (Lake Champlain). The Lake Champlain population has existed for at least two years, if not longer. Thus, New Hampshire residents and boaters are being encouraged to arm themselves with knowledge about the natural history and geographic spread of the mussels. Interstate boaters and anglers, in particular, should become familiar with boating and fishing practices that decrease the likelihood that zebra mussels will be transferred from an infested water body to an uninfested one.

The infestation risk factor for any particular water body is determined mainly by the amount and type of boat traffic it supports and the chemical characteristics and temperature it maintains. While the goal is to prevent the mussels from becoming established in New England waters, zebra mussels have proven to be adaptable creatures

able to survive in a growing range of environmental conditions. Cooperative monitoring activities coordinated by the **New Hampshire Lakes Lay Monitoring Program** will help determine if and when zebra mussels become established in this region. If zebra mussels are found, information about control techniques can help those concerned choose the best method to reduce the destructive impacts of the mussels.

To receive more information, request an educational presentation for your next group meeting, become involved in monitoring efforts, or confirm an identification, contact:

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MOTORIZED BOATING ON LAKES: WHAT ARE THE ENVIRONMENTAL IMPACTS?

Jeff Schloss UNH Cooperative Extension Water Resources Specialist and
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Introduction

A large speed-boat with the power of over two hundred horses driving its propeller zooms around the shallow five acre lake. On any summer weekend, the line of boats passing through the bay to enter the big lake overflows the channel. These and similar events are occurring more often on our lakes. Throughout the state boating has become increasingly popular. In fact, boat sales in New Hampshire are rising to record levels with increases in both average boat size and average engine power. Should we be concerned for our lakes? The answer is not as simple as it might appear to be.

What determines a motorboat's environmental impact on a lake? Dr. Kenneth Wagner, an environmental consultant for Fugro, a firm in Massachusetts, is perhaps the nearest thing to a local expert on this matter. He has compiled the results of historical and recent studies of impacts of motorized craft on a variety of waters, for publications of the North American Lakes Management Society, and has coordinated boat impact research studies in New York and Massachusetts. Much of the material to be discussed in this article has been summarized in his re-

views. I will also expand upon results of our own studies conducted on specific New Hampshire lakes with the assistance of volunteer monitors in our NH LLMP program. Finally, some precautions and considerations will be discussed in light of this complex topic.

Potential Impacts

Motorized watercraft have the potential to impact water quality and related resources through direct and indirect ways. Fuel from motor exhaust can directly add hydrocarbons, metals and even phosphorus (a nutrient that can cause excessive algae and plant growth) into the water. Older (pre-1979) two-cycle outboards, can discharge as much as one third to one half of the fuel used unburned directly into the water. This is in addition to the pollutants from the combusted fuel and oil mixture. Inboard and larger outboard engines, however, are four-cycle in design which operate much cleaner. In addition, recent advances in outboards include new four cycle models and two-cycle engines with solid state ignition and fuel injection which are more efficient and burn cleaner than older models. Fuel and oil in water can also result from spills and leaks during maintenance and fueling.

Generally, studies have shown fuel and related pollution problems tend to be significant only when boats are in dense concentrations on the water or in and around large marinas.

Indirect impacts from boating are related to the generation of a wake and the extent of the turbulence caused by the propeller. The extent of these disturbances is dependent on the hull design, engine power and speed of the craft. A speeding bass boat planing at 30 knots can produce less of a wake than a bow-rider traveling at 10 knots. A 50 hp outboard can produce turbulence down below 15 feet. Jet watercraft create less turbulence downward but cause more concentrated horizontal turbulence. This advantage may be negated though, by the fact that these "jet-ski's" are often observed speeding in very shallow waters.

These processes have the potential to fragment aquatic plants, re-suspend bottom material and erode shallow and shoreline areas. Fragmenting plants can spread their range into new areas since most plants can regenerate from fragments. Re-suspending the lake sediment and eroding the shoreline can create turbid water conditions. Nutrients are generally attached to or associated with re-suspended particles resulting in increased phosphorus levels in the upper waters. These conditions can favor nuisance algae blooms while suppressing native aquatic plant growth in deeper waters. Erosion or burial of habitat areas for aquatic organisms are additional concerns as are conditions conducive to causing stress or abandonment of bird and fish nesting areas.

Other researchers have argued that wakes and turbulence from boats may have less impact than wind induced turbulence. However, personal

observations on windy days suggest that wind causes more of a lapping pattern against the shoreline while the wake of a motorcraft often rides into shore as a large wave which has higher erosion potential. Wind impacts are also more dependent on the "fetch" of a lake (the distance over water that the wind can blow with no obstructions) while boat impacts can occur on virtually any lake.

Boat Impact Studies

Highly variable impacts have been documented for lakes in New Hampshire dependent on the number of boats operating and differing lake characteristics. An 80 hp boat towing a skier around Beaver Lake in Derry caused a seven foot decrease in water clarity within 5 minutes. After two hours with no activity, the lake still had not fully recovered. At Squaw Cove in Squam Lake, transparency during the circling of a boat decreased only by about a foot and almost immediately recovered. At another deeper cove on the same lake, transparency decreased by almost three feet. Differences in these cases relate to the bottom material and shoreline character of the test areas. Squaw cove has a very sandy bottom and has a well vegetated (protected from erosion) shoreline. The other Squam cove has a less protected shoreline and more fine bottom materials while Beaver Lake has a predominately muddy bottom with a very unprotected shoreline.

Nutrient impacts were also dependent on these same characteristics. The nutrient levels at both Squam sites increased by only two to three units (from 2 to 5 parts per billion of the nutrient phosphorus) with no corresponding algae response. In contrast, nutrients increased over tenfold (from 8 to 88 parts per billion) after a busy boating day at Conway Lake. This resulted in a

doubling of the algae levels the following day. Conway lake has a very organic (mucky) bottom with two deep basins and a lot of shallows. Some shoreline is protected but a substantial amount is cleared. Another observation from our monitoring involving boat impacts is the re-suspension of nuisance algae from mats growing on shallow lake bottoms, from layers that often concentrate at the middle depths of deeper lakes, and from species growing within underwater weed beds (the "clouds" of algae we sometimes see floating around).

Thus, motor craft impacts may differ due to lake area, bottom sediment composition, weed bed extent, shallowness, shoreline development and shoreline condition (slope, soils, and vegetative cover).

Final Considerations

Given all of the potential impacts that motoring across the waters can have on your lake- what's a caring enthusiast to do? Some simple precautions and practices can greatly help to minimize impacts and might even prevent future conflicts:

- Take care when you fuel your boat and do not overfill. Deal with oil and gas leaks and dirty bilge water in the proper manner (absorbent pads disposed of properly instead of flushing into the lake).
- If you plan to purchase a new outboard motor think about a four cycle model or a two cycle with electronic fuel injection to keep pollutant discharges down. Keeping whatever engine you have in tune will also minimize your impacts.
- Never use harsh chemical boat products where they can run off into the lake. If there is a warning on the label for humans it most likely has an even greater impact on aquatic

life. The same goes for washing your boat. Even low phosphorus detergents can augment algae growth.

- When out on the water, follow the safe boating distances and respect the no wake zones. Avoid shallow water whenever possible to prevent sediment re-suspension and habitat destruction. Keep clear of known nesting areas of waterfowl and fish (for example: smallmouth bass tend to nest in rocky shoals). If you must cross into shallow waters maintain headway speed and minimize your wake at all times.
- If you have a choice of areas to water-ski or use personal watercraft, pick those locations that are over the deepest waters, are farthest from shore and that have the most protected (vegetated) shorelines visible.
- Make sure that you are not assisting in the spread of noxious and non-native plants and animals (millfoil, cabomba weed, zebra mussels). Check your watercraft, trailer and vehicle for these "hitchhikers". Also check all gear, live-wells and bilge. Keep out of shallow weed beds to prevent further spread of native weeds.
- If you are visiting a lake by boat, plan ahead by making note of the nearest toilets available. Pack out all that you brought onto the water. Take care of where you choose to anchor in relation to lake wildlife, their habitat areas, and your location with respect to others.

Most importantly, remember that a positive lake experience can be many different things to different people. Issues of user conflicts (canoes or sailcraft versus motorboats, anglers versus water-skiers), and aesthetics are important components that are not directly related to the resource impacts.

They do, however, often incite emotional responses. Some lakes in our state have addressed these sorts of conflicts by limiting access, using activity zones that restrict areas where certain types of boating can take place or by maintaining time restrictions for various boating activities. In the end, we may never come to full resolution of these issues. However, understanding the potential negative impacts for a given lake's characteristics and resources could lead to an acceptable compromise.

NOTE: This is an expanded version of an article requested for the New Hampshire Lake Association's Newsletter (Spring 1995).

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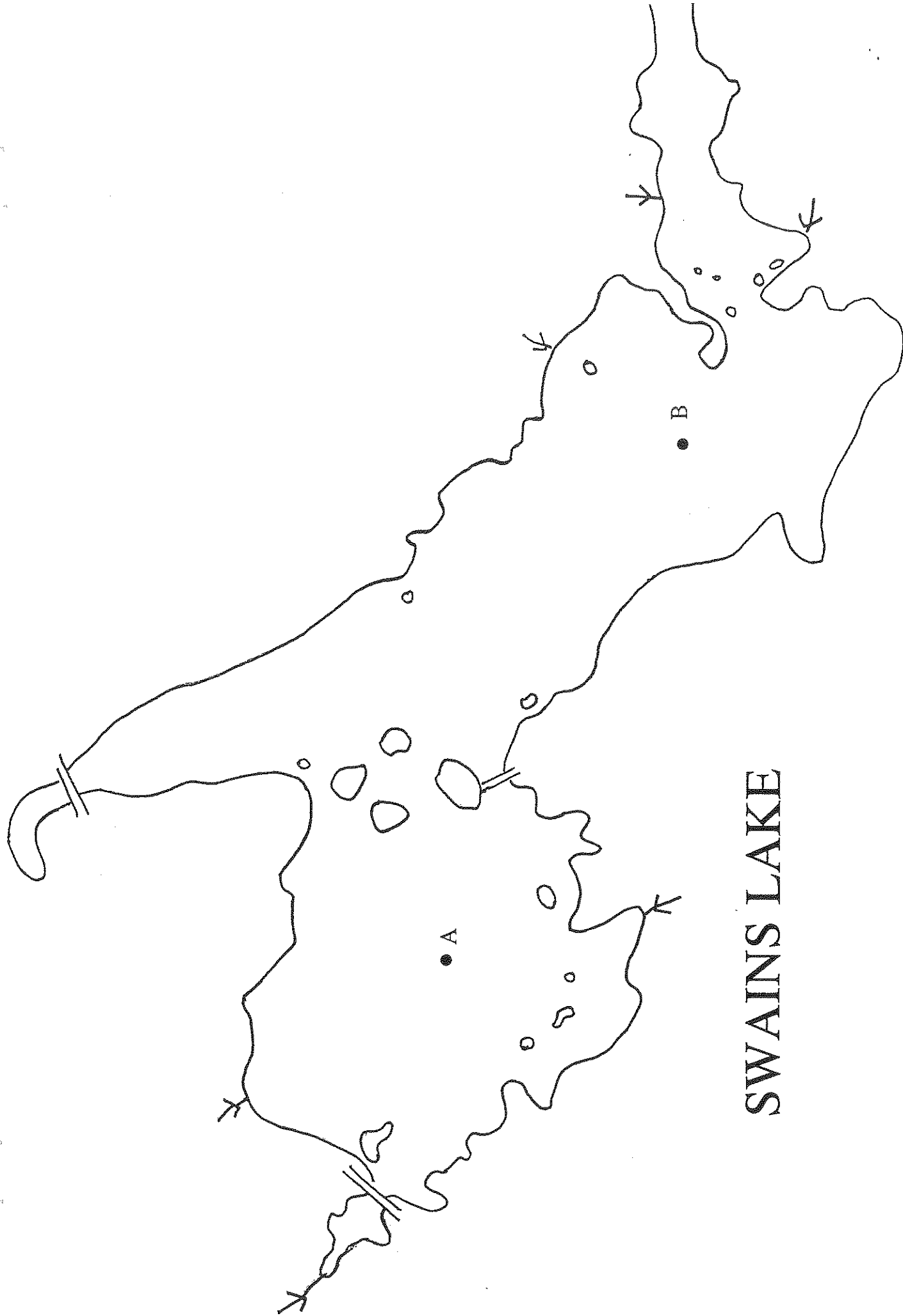
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REPORT FIGURES

Figure 5. Location of the 1994 Swain's Lake deep sampling stations;
Sites A and B, Strafford, New Hampshire.



SWAINS LAKE

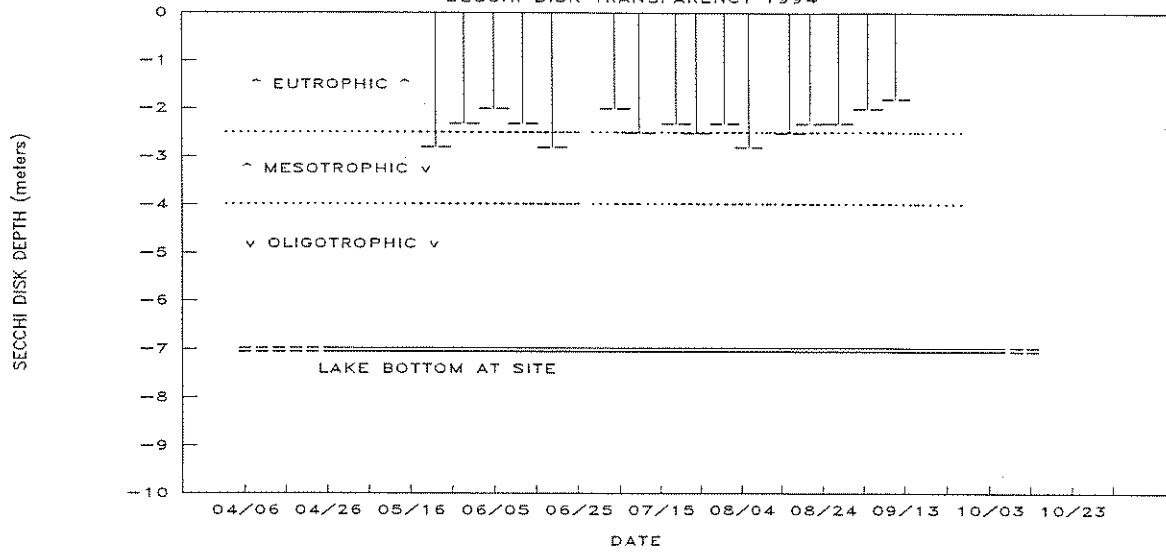
Figure 6. Swains Lake, 1994. Seasonal Secchi Disk (water transparency) trends for lay monitor Site A. The dotted horizontal lines on the plot border the ranges common to oligotrophic, mesotrophic and eutrophic lakes.

Figure 7. Swain's Lake, 1994. Seasonal chlorophyll *a* trends for lay monitor Site A. Chlorophyll *a* concentrations are expressed as parts per billion (ppb) chlorophyll *a*. The dotted horizontal lines on the plot border the ranges common to oligotrophic, mesotrophic and eutrophic lakes.

Figure 8. Swain's Lake, 1994. Seasonal dissolved color trends for lay monitor Site A. Dissolved color is expressed as platinum-cobalt units (ptu). The dotted horizontal line represents the dissolved color average for participating **LLMP** lakes.

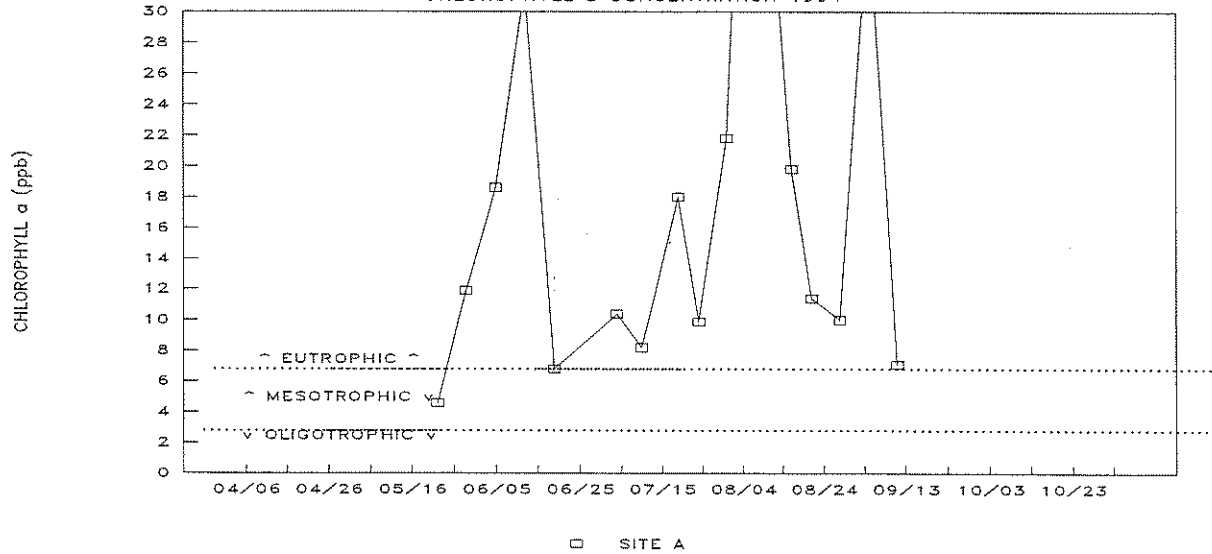
SWAIN'S LAKE — SITE A

SECCHI DISK TRANSPARENCY 1994



SWAIN'S LAKE

CHLOROPHYLL *a* CONCENTRATION 1994



SWAIN'S LAKE

DISSOLVED COLOR CONCENTRATION 1994

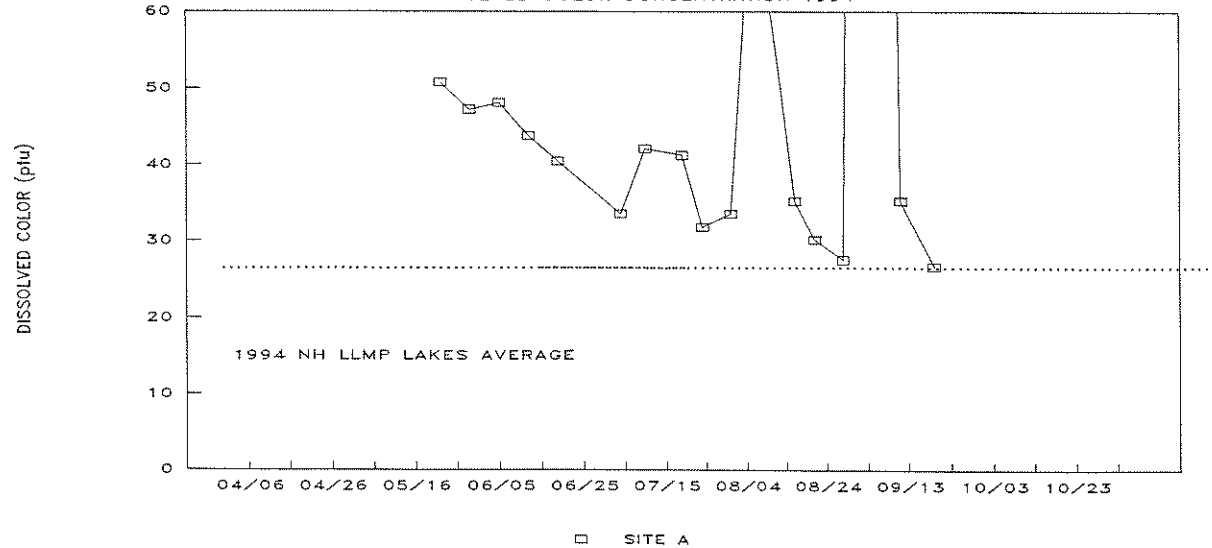
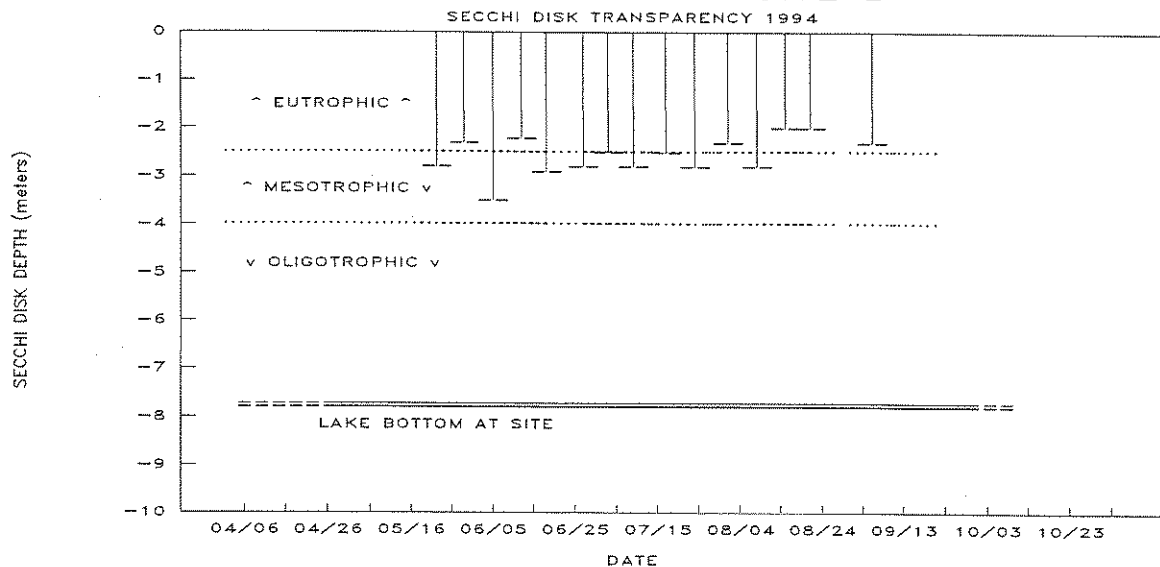


Figure 9. Swain's Lake, 1994. Seasonal Secchi Disk (water transparency) trends for lay monitor Site B. The dotted horizontal lines on the plot border the ranges common to oligotrophic, mesotrophic and eutrophic lakes.

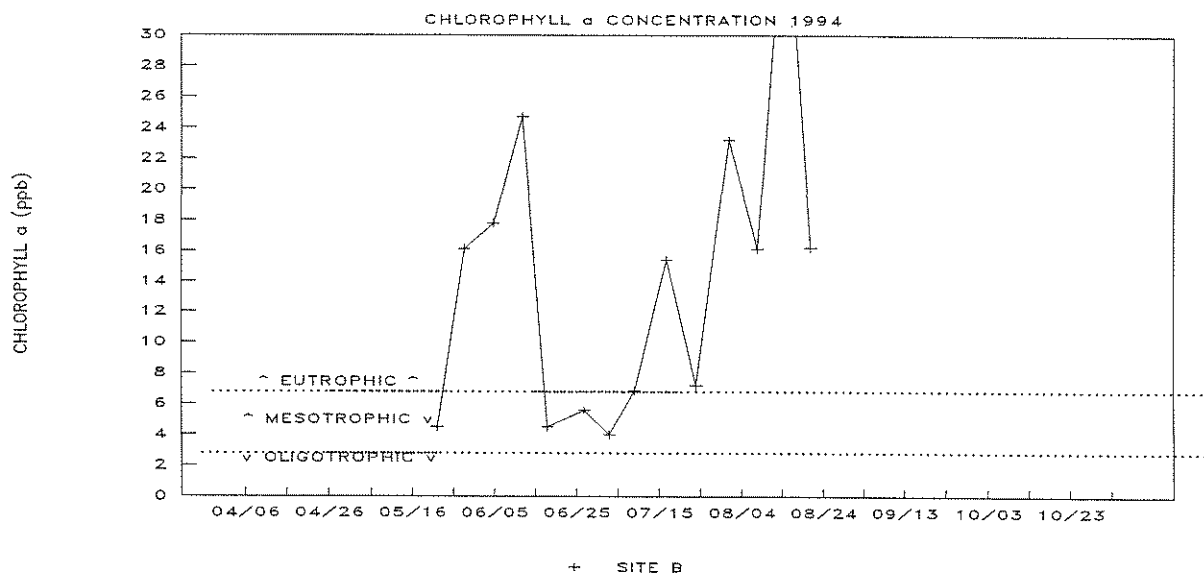
Figure 10. Swains Lake, 1994. Seasonal chlorophyll α trends for lay monitor Site B. Chlorophyll α concentrations are expressed as parts per billion (ppb) chlorophyll α . The dotted horizontal lines on the plot border the ranges common to oligotrophic, mesotrophic and eutrophic lakes.

Figure 11. Swain's Lake, 1994. Seasonal dissolved color trends for lay monitor Site B. Dissolved color is expressed as platinum-cobalt units (ptu). The dotted horizontal line represents the dissolved color average for participating **LLMP** lakes.

SWAIN'S LAKE — SITE B



SWAIN'S LAKE



SWAIN'S LAKE

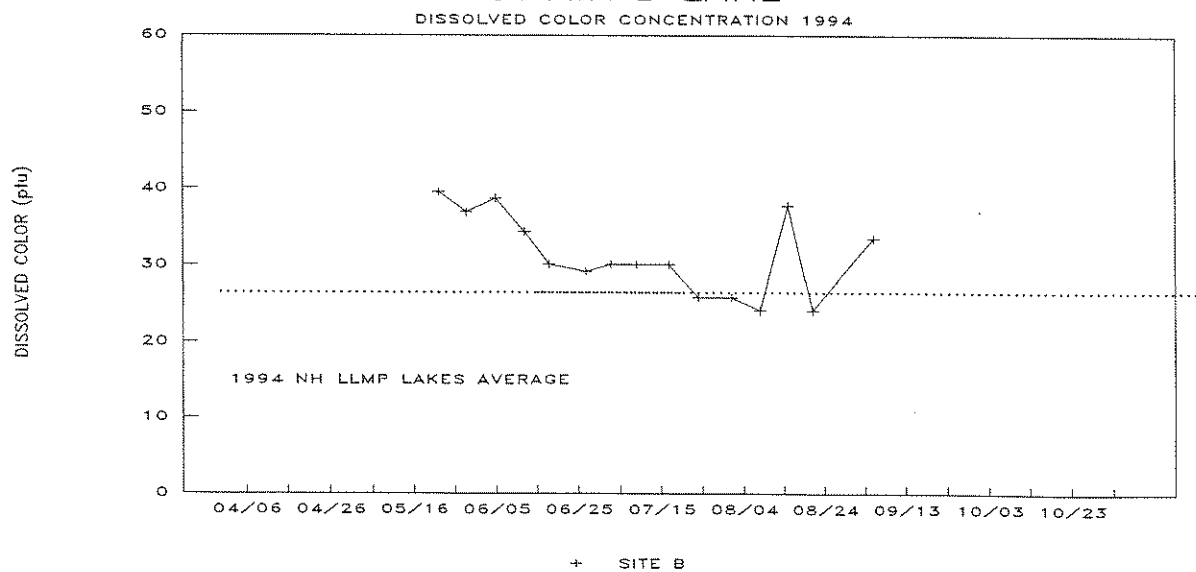


Figure 12. Swain's Lake, 1994. Seasonal chlorophyll *a* trends for lay monitor Sites A (squares) and B (crosses). Chlorophyll *a* concentrations are expressed as parts per billion (ppb) chlorophyll *a*. The dotted horizontal lines on the plot border the ranges common to oligotrophic, mesotrophic and eutrophic lakes.

Figure 13. Swain's Lake, 1994. Seasonal dissolved color trends for lay monitor Sites A (squares) and B (crosses). Dissolved color is expressed as platinum-cobalt units (ptu). The dotted horizontal line represents the dissolved color average for participating **LLMP** lakes.

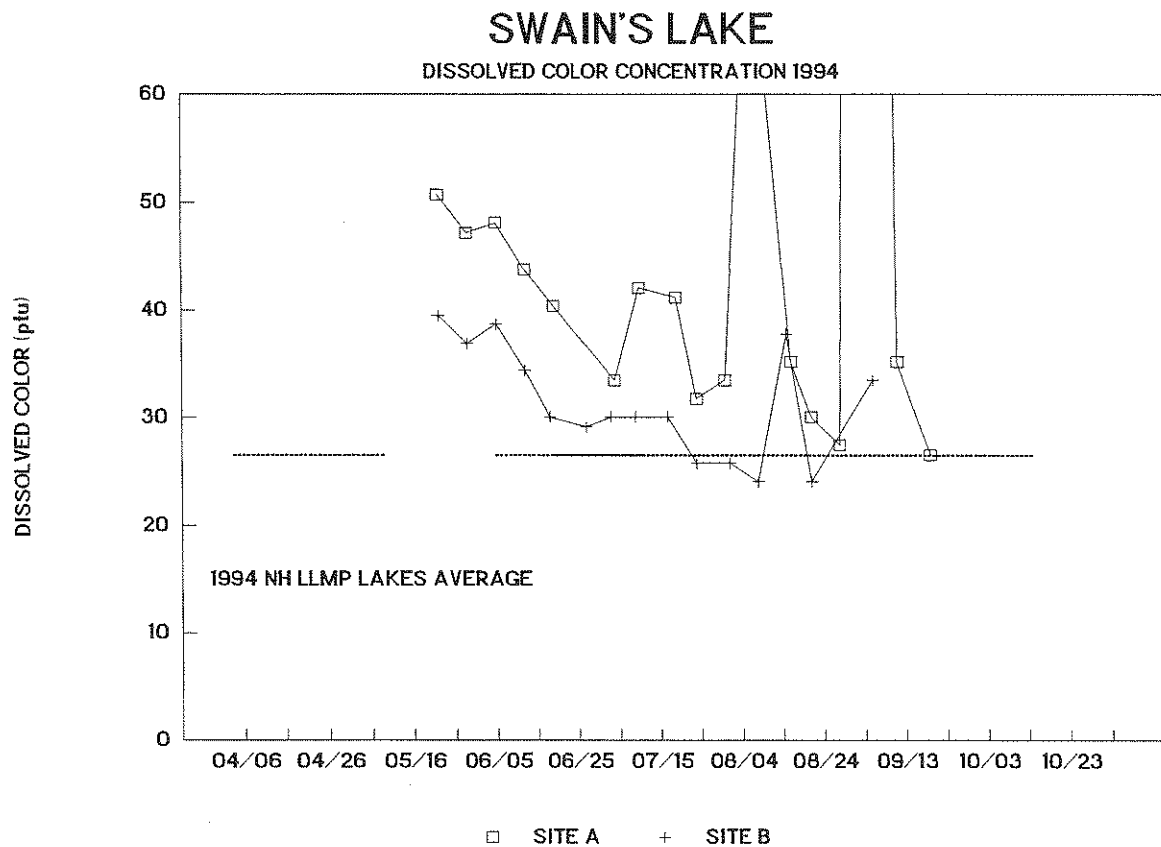
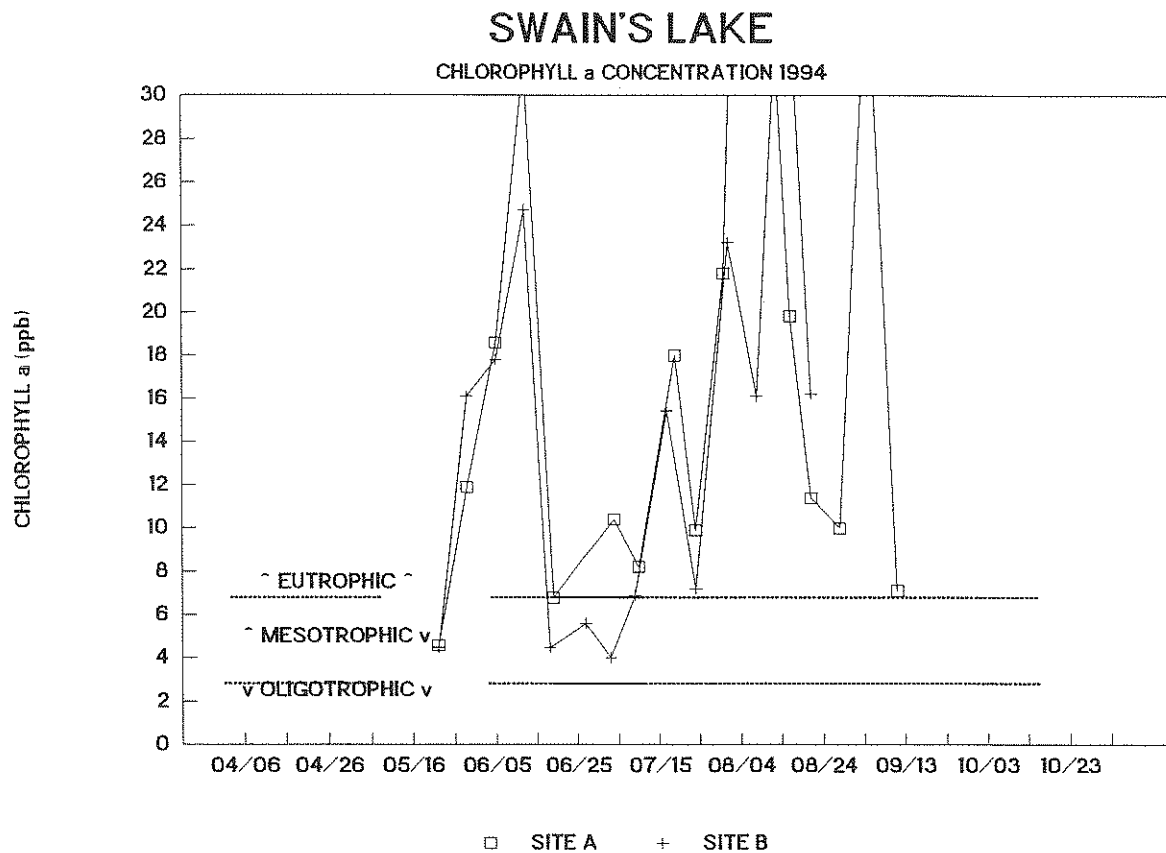
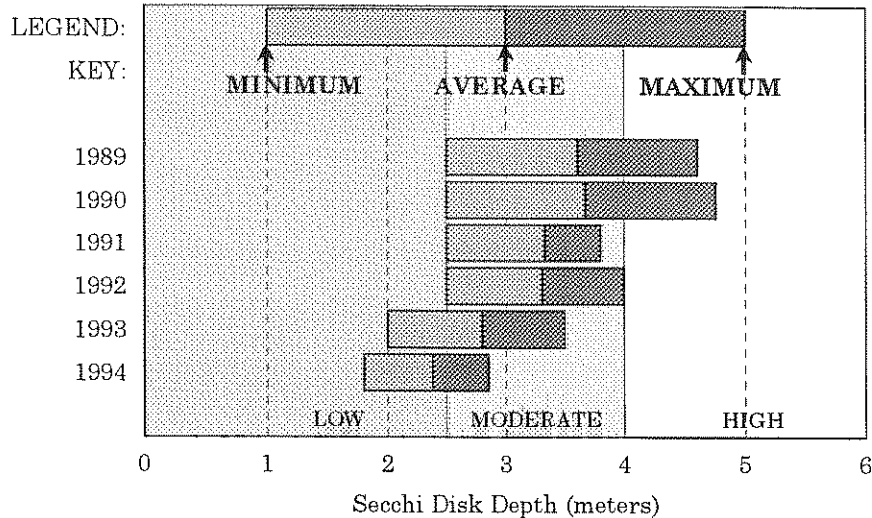


Figure 14. Comparison of the 1994 Swain's Lake, Site A, lay monitor Secchi Disk transparency data with previous yearly data. The patterns of the bars display the minimum, average and maximum values for the respective years sampled while the length of the bars represents the total range of values. The shaded regions on the graph denote the ranges characteristic of low, moderate and high Secchi Disk transparencies. The higher the Secchi Disk value the clearer the water. Secchi Disk readings are measured to the nearest tenth (0.1) of a meter.

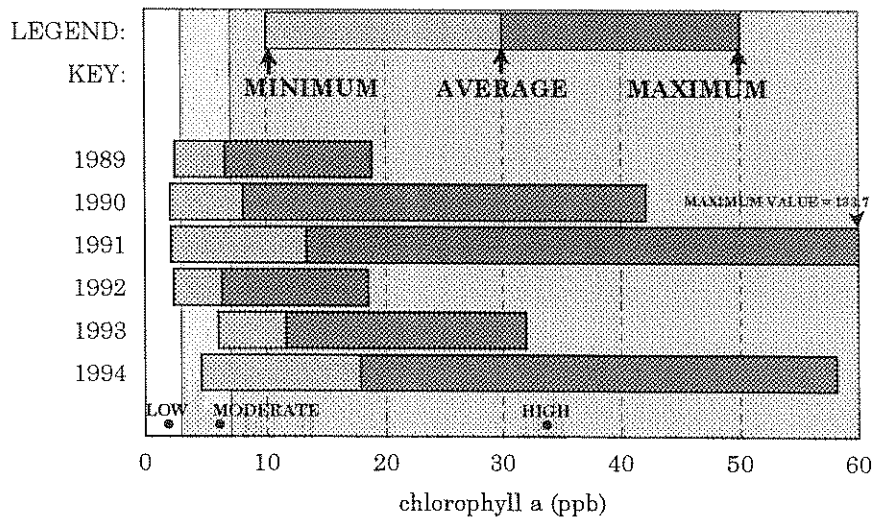
Figure 15. Comparison of the 1994 Swain's Lake, Site A, lay monitor chlorophyll *a* data with previous yearly data. The patterns of the bars display the minimum, average and maximum values for the respective years sampled while the length of the bars represents the total range of values. The shaded regions on the graph denote the ranges characteristic of low, moderate and high chlorophyll *a* concentrations. The higher the chlorophyll *a* concentration the greener the water (i.e. more algal growth).

SWAIN'S LAKE - SITE A **LAY MONITOR SECCHI DISK DATA** **YEARLY COMPARISONS (1989-1994)**



The higher value = clearer water

SWAIN'S LAKE - SITE A **LAY MONITOR CHLOROPHYLL *a* DATA** **YEARLY COMPARISONS (1989-1994)**

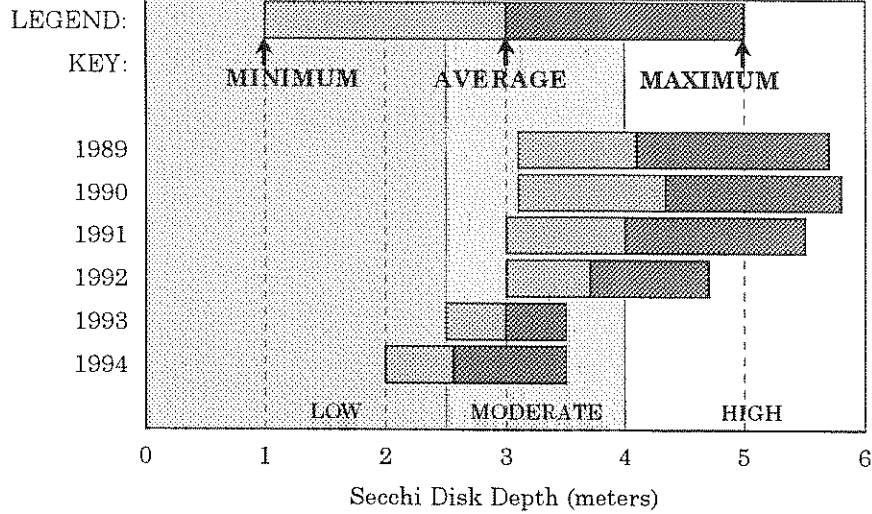


The higher value = more algal growth

Figure 16. Comparison of the 1994 Swain's Lake, Site B, lay monitor Secchi Disk transparency data with previous yearly data. The patterns of the bars display the minimum, average and maximum values for the respective years sampled while the length of the bars represents the total range of values. The shaded regions on the graph denote the ranges characteristic of low, moderate and high Secchi Disk transparencies. The higher the Secchi Disk value the clearer the water. Secchi Disk readings are measured to the nearest tenth (0.1) of a meter.

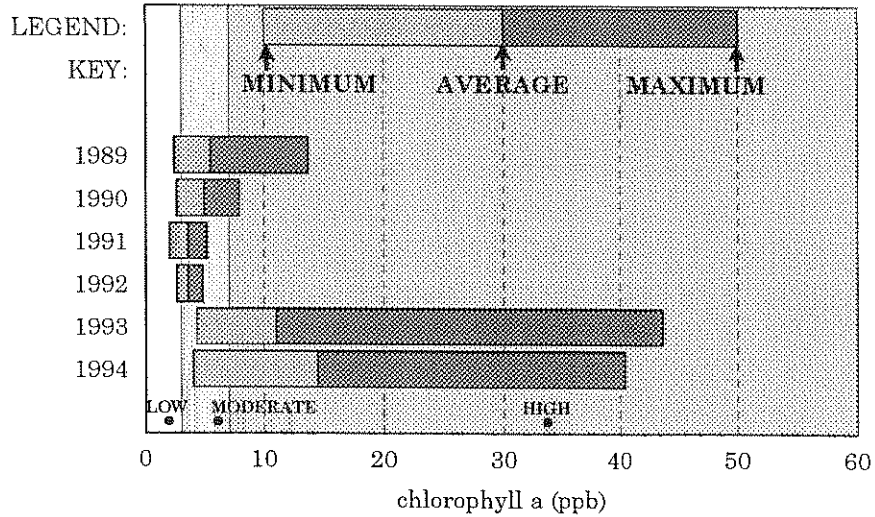
Figure 17. Comparison of the 1994 Swain's Lake, Site B, lay monitor chlorophyll α data with previous yearly data. The patterns of the bars display the minimum, average and maximum values for the respective years sampled while the length of the bars represents the total range of values. The shaded regions on the graph denote the ranges characteristic of low, moderate and high chlorophyll α concentrations. The higher the chlorophyll α concentration the greener the water (i.e. more algal growth).

SWAIN'S LAKE - SITE B **LAY MONITOR SECCHI DISK DATA** **YEARLY COMPARISONS (1989-1994)**



The higher value = clearer water

SWAIN'S LAKE - SITE B **LAY MONITOR CHLOROPHYLL *a* DATA** **YEARLY COMPARISONS (1989-1994)**

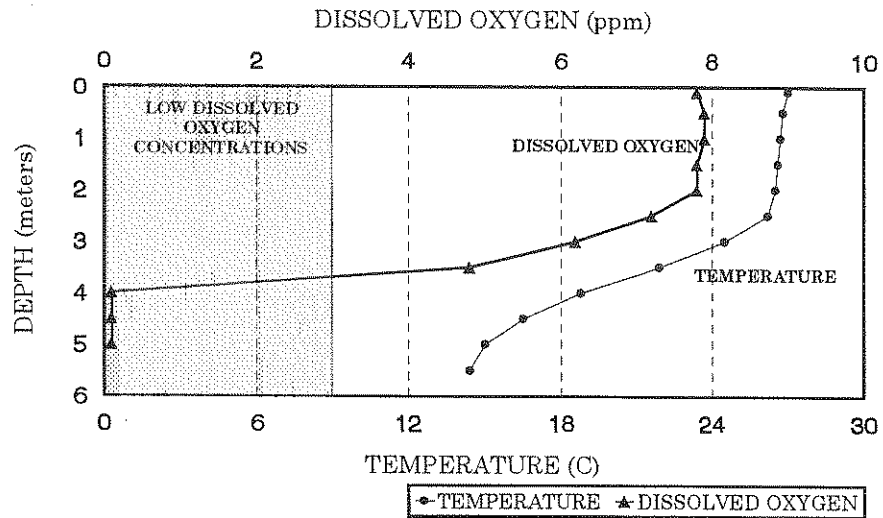


The higher value = more algal growth

Figure 18. Temperature and dissolved oxygen profiles collected at the Swain's Lake deep sampling station: Site A, on July 8 and August 19, 1994. The dissolved oxygen and temperature readings were measured at one-half meter intervals. Notice the low dissolved oxygen concentrations in the deeper waters (see text).

SWAINS LAKE - SITE A

JULY 8, 1994



SWAINS LAKE - SITE A

AUGUST 19, 1994

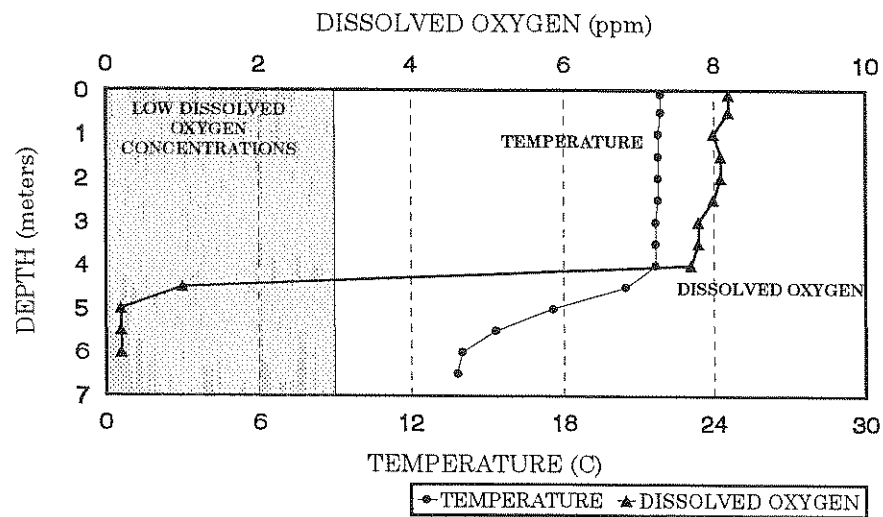
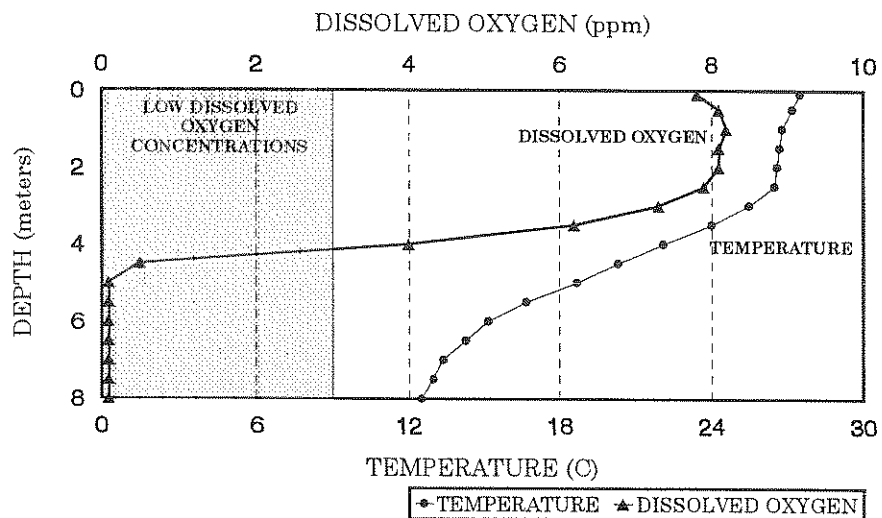


Figure 19. Temperature and dissolved oxygen profiles collected at the Swain's Lake deep sampling station: Site B, on July 8 and August 19, 1994. The dissolved oxygen and temperature readings were measured at one-half meter intervals. Notice the low dissolved oxygen concentrations in the deeper waters (see text).

SWAINS LAKE - SITE B

JULY 8, 1994



SWAINS LAKE - SITE B

AUGUST 19, 1994

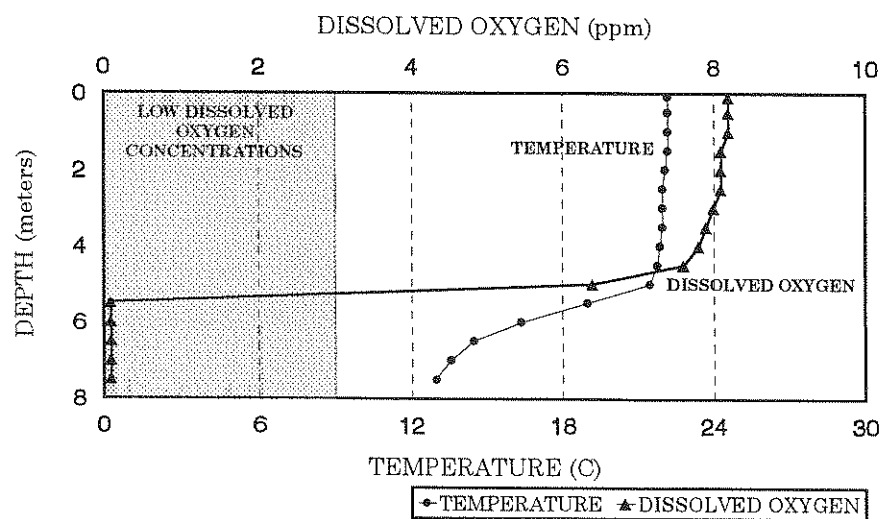


Figure 20. Pie diagrams of phytoplankton diversity representing data collected at the Swain's Lake deep sampling station: Site A, on July 8, 1994 and August 19, 1994. The sample depths are as indicated above the respective graphs. The phytoplankton abundance is presented as percent composition by algal class.

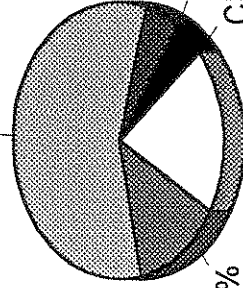
SWAINS LAKE

Site A

July 8, 1994

Depth : 0 - 2.5 meters

UNID. FLAGELLATES 57.3%



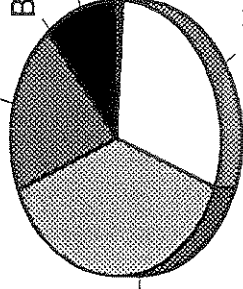
GREENS 13.5%

DIATOMS/GOLDENS 19.4%

DINOFLAGELLATES 5.2%

CRYPTOMONADS 4.6%

UNID. FLAGELLATES 38.3%



GREENS 20.0%

BLUEGREENS 0.5%

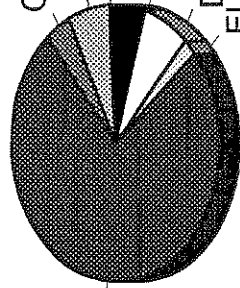
CRYPTOMONADS 10.2%

DINOFLAGELLATES 1.3%

DIATOMS/GOLDENS 29.6%

August 19, 1994

Depth : 5.0 meters



BLUEGREENS 75.2%

GREENS 4.0%

UNID. FLAGELLATES 6.3%

DINOFLAGELLATES 0.2%

CRYPTOMONADS 5.2%

DIATOMS/GOLDENS 7.1%

EUGLENOIDS 2.1%

Phytoplankton densities are presented as % abundance by algal class.

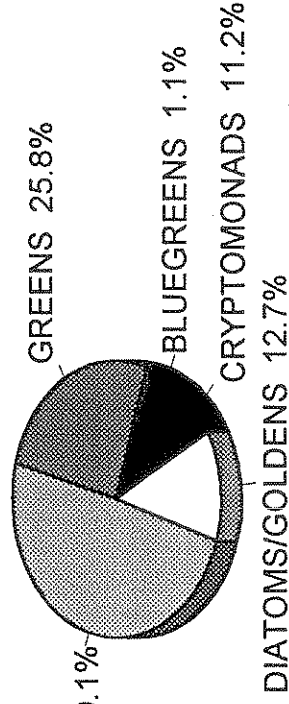
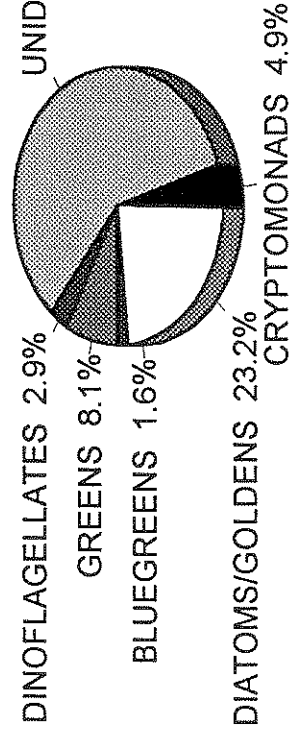
Figure 21. Pie diagrams of phytoplankton diversity representing data collected at the Swain's Lake deep sampling station: Site B, on July 8, 1994 and August 19, 1994. The sample depths are as indicated above the respective graphs. The phytoplankton abundance is presented as percent composition by algal class.

SWAINS LAKE

Site B

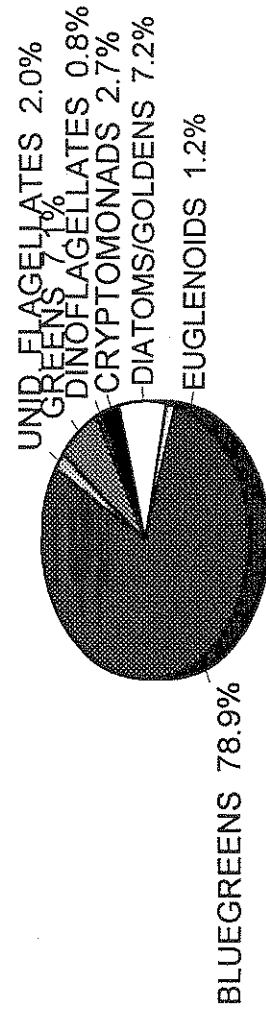
July 8, 1994

Depth : 0 - 2.5 meters



August 19, 1994

Depth : 6.0 meters



Phytoplankton densities are presented as % abundance by algal class.

Figure 22. Pie diagrams of macro-zooplankton abundance representing data collected at the Swain's Lake deep sampling stations: Site A and Site B, on July 8, 1994 and on August 19, 1994. The site names and sample depths are printed above the respective graphs. The macro-zooplankton densities are presented as the number of organisms per liter.

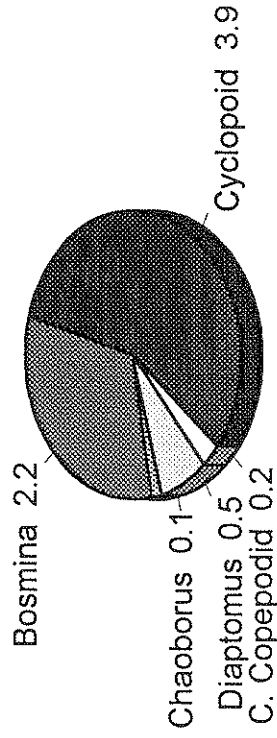
Swains Lake

July 8, 1994

August 19, 1994

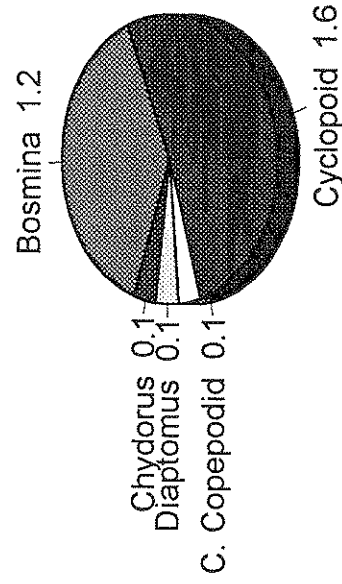
Site A

Depth of Tow : 0 - 3.5 meters



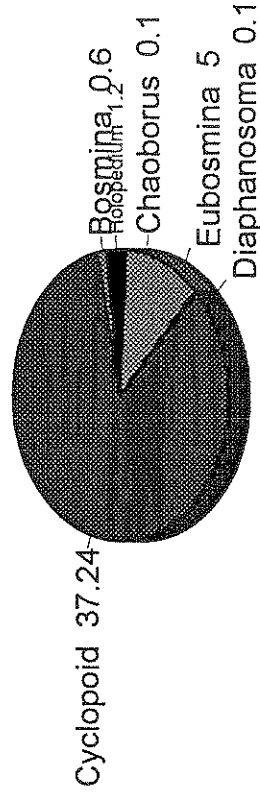
Site B

Depth of Tow : 0 - 4.0 meters



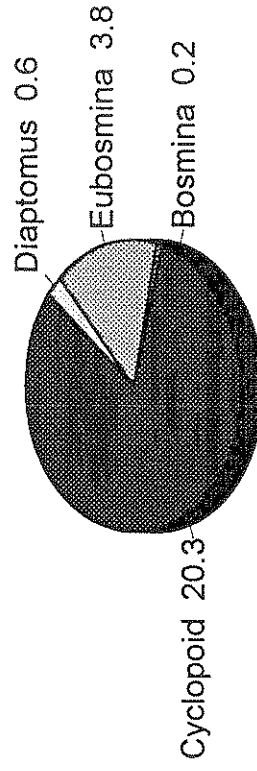
Site A

Depth of Tow : 0 - 4.0 meters



Site B

Depth of Tow: 0-5.0 meters



Macrozooplankton densities are presented as # animals per liter.

APPENDIX A

Lakes Lay Monitoring Program, U.N.H.

[Lay Monitor Data]

Swains Pond, NH

-- subset of trophic indicators, all sites, 1994

1994 SUMMARY

Average transparency: 2.4 (1994: 31 values; 1.8 - 3.5 range)
 Average chlorophyll: 16.3 (1994: 30 values; 4.0 - 58.1 range)
 Average alk (gray): 1.8 (1994: 30 values; 1.0 - 4.2 range)
 Average alk (pink): 2.9 (1994: 30 values; 1.9 - 6.0 range)
 Average color, 440: 46.5 (1994: 32 values; 24.1 - 371.1 range)

Site	Date	Trans- parency (m)	Chl a (ppb)	Total Phos (ppb)	Alk. (gray) ph 5.1	Alk. (pink) ph 4.6	Color Pt-Co units
A	05/22/1994	2.8	4.6	----	1.6	2.4	50.7
A	05/29/1994	2.3	11.9	----	1.4	2.1	47.2
A	06/05/1994	2.0	18.6	----	1.3	2.0	48.1
A	06/12/1994	2.3	31.7	----	1.2	2.0	43.8
A	06/19/1994	2.8	6.8	----	1.2	2.3	40.4
A	07/04/1994	2.0	10.4	----	1.7	2.3	33.5
A	07/10/1994	2.5	8.2	----	1.8	2.8	42.1
A	07/19/1994	2.3	18.0	----	2.1	3.4	41.2
A	07/24/1994	2.5	9.9	----	1.7	2.4	31.8
A	07/31/1994	2.3	21.8	----	1.8	2.8	33.5
A	08/06/1994	2.8	58.1	----	4.2	5.9	79.9
A	08/16/1994	2.5	19.8	----	2.5	4.0	35.2
A	08/21/1994	2.3	11.4	----	2.0	3.0	30.1
A	08/28/1994	2.3	10.0	----	2.0	2.7	27.5
A	09/04/1994	2.0	36.6	----	----	----	371.1
A	09/11/1994	1.8	7.1	----	1.7	3.2	35.2
A	09/19/1994	----	----	----	1.9	2.7	26.6
B	05/22/1994	2.8	4.5	----	1.4	2.1	39.5
B	05/29/1994	2.3	16.1	----	1.5	2.2	36.9
B	06/05/1994	3.5	17.8	----	1.2	1.9	38.7
B	06/12/1994	2.2	24.7	----	1.2	2.0	34.4
B	06/18/1994	2.9	4.5	----	1.0	2.5	30.1
B	06/27/1994	2.8	5.6	----	1.6	2.5	29.2
B	07/03/1994	2.5	4.0	----	2.0	2.8	30.1
B	07/09/1994	2.8	6.9	----	1.8	3.0	30.1
B	07/17/1994	2.5	15.4	----	1.8	3.3	30.1
B	07/24/1994	2.8	7.2	----	2.0	2.6	25.8
B	08/01/1994	2.3	23.2	----	1.6	3.0	25.8

Site	Date	Trans- parency (m)	Chl a (ppb)	Total Phos (ppb)	Alk. (gray) ph 5.1	Alk. (pink) ph 4.6	Color Pt-Co units
-----	-----	-----	-----	-----	-----	-----	-----
B	08/08/1994	2.8	16.1	----	2.0	3.3	24.1
B	08/15/1994	2.0	40.5	----	4.0	6.0	37.8
B	08/21/1994	2.0	16.2	----	2.2	3.7	24.1
B	09/05/1994	2.3	----	----	----	----	33.5

<< End of 1994 listing, 32 records >>

Historical Lay Monitor Secchi Disk Data (1989-1994)

Lake	Site	Year	Minimum Secchi Disk Depth (meters)	Average Secchi Disk Depth (meters)	Maximum Secchi Disk Depth (meters)	Sample Size
Swains	A	1989	2.5	3.6	4.6	13
Swains	A	1990	2.5	3.7	4.8	17
Swains	A	1991	2.5	3.3	3.8	14
Swains	A	1992	2.5	3.3	4.0	8
Swains	A	1993	2.0	2.8	3.5	10
Swains	A	1994	1.8	2.3	2.8	16
Swains	B	1989	3.1	4.1	5.7	13
Swains	B	1990	3.1	4.3	5.8	18
Swains	B	1991	3.0	4.0	5.5	14
Swains	B	1992	3.0	3.7	4.7	10
Swains	B	1993	2.5	3.0	3.5	11
Swains	B	1994	2.0	2.6	3.5	15

Historical Lay Monitor Chlorophyll a Data (1989-1994)

Lake	Site	Year	Minimum Chloro- phyll a (ppb)	Average Chloro- phyll a (ppb)	Maximum Chloro- phyll a (ppb)	Sample Size
Swains	A	1989	2.5	6.6	18.8	13
Swains	A	1990	2.1	8.0	42.1	18
Swains	A	1991	2.2	13.4	133.7	14
Swains	A	1992	2.4	6.3	18.5	8
Swains	A	1993	6.0	11.6	31.9	10
Swains	A	1994	4.6	17.8	58.1	16
Swains	B	1989	2.4	5.5	13.7	13
Swains	B	1990	2.6	5.0	7.9	18
Swains	B	1991	2.0	3.5	5.1	14
Swains	B	1992	2.6	3.6	4.8	10
Swains	B	1993	4.3	11.1	43.7	11
Swains	B	1994	4.0	14.5	40.5	14

Swain's Lake - Site A (FBG data)

JUL-08-1994

Depth (meters)	Chloro- phyll a (ppb)	Color (ptu)	Total phos. (ppb)	SPCD (uS)	pH	CO ₂ (mg/l)	Alk Gray end pt.	Alk Pink end pt.
0-2.5	5.4	40.4	14.8	40.3	6.3	1.1	0.8	1.1
0.5	7.0	28.3	----	40.2	6.3	1.2	0.5	0.8
1.0	----	----	----	40.3	6.3	0.8	0.8	1.1
3.5	27.6	29.2	20.3	40.7	6.2	2.0	1.0	1.4
4.5	----	----	39.4	52.2	6.0	>22.0	9.5	9.8

Secchi Disk Depth = 2.7 meters

Depth (meters)	Tem- pera- ture (°C)	Diss. oxygen (mg/l)
0.10	27.0	7.8
0.50	26.8	7.9
1.00	26.7	7.9
1.50	26.6	7.8
2.00	26.5	7.8
2.50	26.2	7.2
3.00	24.5	6.2
3.50	21.9	4.8
4.00	18.8	0.1
4.50	16.5	0.1
5.00	15.0	0.1
5.50	14.4	----

Swain's Lake - Site A (FBG data)

AUG-19-1994

Depth (meters)	Chloro- phyll a (ppb)	Color (ptu)	Total phos. (ppb)	SPCD (uS)	pH	CO ₂ (mg/l)	Alk Gray end pt.	Alk Pink end pt.
0-4.0	13.9	26.6	16.9	38.9	6.3	----	1.5	1.8
0.5	13.7	28.3	----	38.8	6.3	1.0	1.3	1.7
2.0	----	----	----	39.9	6.3	1.2	1.4	1.7
5.0	57.5	114.2	----	43.6	5.9	9.0	5.7	6.5
6.0	101.4	636.5	62.4	55.2	6.2	>22.0	13.9	14.6

Depth (meters)	Tem- pera- ture (°C)	Diss. oxygen (mg/l)
0.10	21.9	8.2
0.50	21.9	8.2
1.00	21.8	8.0
1.50	21.8	8.1
2.00	21.8	8.1
2.50	21.8	8.0
3.00	21.7	7.8
3.50	21.7	7.8
4.00	21.7	7.7
4.50	20.5	1.0
5.00	17.6	0.2
5.50	15.3	0.2
6.00	14.0	0.2
6.50	13.8	----

Swain's Lake - Site B (FBG data)

JUL-08-1994

Depth (meters)	Chloro- phyll a (ppb)	Color (ptu)	Total phos. (ppb)	SPCD (uS)	pH	CO ₂ (mg/l)	Alk Gray end pt.	Alk Pink end pt.
0-2.5	7.9	23.2	13.6	41.3	6.3	1.2	1.2	1.6
0.5	6.1	23.2	----	40.4	6.3	1.2	0.8	1.3
1.5	----	----	----	40.5	6.3	0.9	0.8	1.1
3.5	18.4	24.1	16.0	41.0	6.2	1.7	1.3	1.6
7.0	----	----	33.2	55.7	6.0	12.2	11.2	11.8

Secchi Disk Depth = 2.8 meters

Depth (meters)	Tem- pera- ture (°C)	Diss. oxygen (mg/l)
0.10	27.5	7.8
0.50	27.2	8.1
1.00	26.8	8.2
1.50	26.7	8.1
2.00	26.6	8.1
2.50	26.5	7.9
3.00	25.5	7.3
3.50	24.0	6.2
4.00	22.1	4.0
4.50	20.3	0.5
5.00	18.7	0.1
5.50	16.7	0.1
6.00	15.2	0.1
6.50	14.3	0.1
7.00	13.4	0.1
7.50	13.0	0.1
8.00	12.5	0.1

Swain's Lake - Site B (FBG data)

AUG-19-1994

Depth (meters)	Chloro- phyll a (ppb)	Color (ptu)	Total phos. (ppb)	SPCD (uS)	pH	CO ₂ (mg/l)	Alk Gray end pt.	Alk Pink end pt.
0-5.0	14.0	19.8	13.8	38.9	6.4	----	1.4	1.7
0.5	14.1	20.6	----	39.2	6.3	1.0	1.6	1.9
3.0	----	----	----	39.0	6.3	1.1	1.5	1.8
6.0	67.5	74.7	31.9	45.2	5.9	8.5	7.8	8.6
7.0	91.0	453.6	53.5	55.1	6.2	19.2	25.4	26.7

Secchi Disk Depth = 2.4 meters

Depth (meters)	Tem- pera- ture (°C)	Diss. oxygen (mg/l)
0.10	22.2	8.2
0.50	22.2	8.2
1.00	22.2	8.2
1.50	22.2	8.1
2.00	22.1	8.1
2.50	22.0	8.1
3.00	22.0	8.0
3.50	22.0	7.9
4.00	21.9	7.8
4.50	21.8	7.6
5.00	21.5	6.4
5.50	19.0	0.1
6.00	16.4	0.1
6.50	14.5	0.1
7.00	13.6	0.1
7.50	13.0	0.1

Swains Lake (FBG) tributary sampling, 1994

Site	Date	SPCD (uS)	Total Phos. (ppb)
----	-----	----	-----
T-05	Apr-04	28.7	18.2
T-05	May-04	34.5	30.3
T-10	Apr-04	20.5	11.6
T-10	May-04	18.8	44.8
T-15	Apr-04	31.2	17.7
T-15	May-04	28.1	19.1
T-20	May-04	159.7	8.2
T-25	May-04	122.5	14.0
T-30	Apr-04	35.5	10.6
T-30	May-04	39.1	17.7
T-35	May-04	27.2	27.3
T-40	May-04	95.7	10.9

APPENDIX B

GLOSSARY OF LIMNOLOGICAL TERMS

Aerobe- Organisms requiring oxygen for life. All animals, most algae and some bacteria require oxygen for respiration.

Algae- See phytoplankton.

Alkalinity- Total concentration of bicarbonate and hydroxide ions (in most lakes).

Anaerobe- Organisms not requiring oxygen for life. Some algae and many bacteria are able to respire or ferment without using oxygen.

Anoxic- A system lacking oxygen, therefore incapable of supporting the most common kind of biological respiration, or of supporting oxygen-demanding chemical reactions. The deeper waters of a lake may become anoxic if there are many organisms depleting oxygen via respiration, and there is little or no replenishment of oxygen from photosynthesis or from the atmosphere.

Benthic- Referring to the bottom sediments.

Bacterioplankton- Bacteria adapted to the "open water" or "planktonic" zone of lakes, adapted for many specialized habitats and include groups that can use the sun's energy (phytoplankton), some that can use the energy locked in sulfur or iron, and others that gain energy by decomposing dead material.

Bicarbonate- The most important ion (chemical) involved in the buffering system of New Hampshire lakes.

Buffering- The capacity of lakewater to absorb acid with a minimal change in the pH. In New Hampshire the chemical responsible for buffering is the bicarbonate ion. (See pH.)

Chloride- One of the components of salts dissolved in lakewater. Generally the most abundant ion in New Hampshire lakewater, it may be used as an indicator of raw sewage or of road salt.

Chlorophyll a- The main green pigment in plants. The concentration of chlorophyll *a* in lakewater is often used as an indicator of algal abundance.

Circulation- The period during spring and fall when the combination of low water temperature and wind cause the water column to mix freely over its entire depth.

Density- The weight per volume of a substance. The more dense an object, the heavier it feels. Low-density liquids will float on higher-density liquids.

Dimictic- The thermal pattern of lakes where the lake circulates, or mixes, twice a year. Other patterns such as polymictic (many periods of circulation per year) are uncommon in New Hampshire. (See also meromictic and holomictic).

Dystrophy- The lake trophic state in which the lakewater is highly stained with humic acids (reddish brown or yellow stain) and has low productivity. Chlorophyll *a* concentration may be low or high.

Epilimnion- The uppermost layer of water during periods of thermal stratification. (See lake diagram).

Eutrophy- The lake trophic state in which algal production is high. Associated with eutrophy is low Secchi disk depth, high chlorophyll *a*, and high total phosphorus. From an esthetic viewpoint these lakes are "bad" because water clarity is low, aquatic plants are often found in abundance, and cold-water fish such as trout and salmon are usually not present. A good aspect of eutrophic lakes is their high productivity in terms of warm-water fish such as bass, pickerel, and perch.

Free CO₂- Carbon dioxide that is not combined chemically with lake water or any other substances. It is produced by respiration, and is used by plants and bacteria for photosynthesis.

Holomixis- The condition where the entire lake is free to circulate during periods of overturn. (See meromixis.)

Humic Acids- Dissolved organic compounds released from decomposition of plant leaves and stems. Humic acids are red, brown, or yellow in color and are present in nearly all lakes in New Hampshire. Humic acids are consumed only by fungi, and thus are relatively resistant to biological decomposition.

Hydrogen Ion- The "acid" ion, present in small amounts even in distilled water, but contributed to rain-water by atmospheric processes, to ground-water by soils, and to lakewater by biological organisms and sediments. The active component of "acid rain". See also "pH" the symbolic value inversely and exponentially related to the hydrogen ion.

Hypolimnion- The deepest layer of lakewater during periods of thermal stratification. (See lake diagram)

Lake- Any "inland" body of relatively "standing" water. Includes many synonyms such as ponds, tarns, loches, billabongs, bogs, marshes, etc.

Lake Morphology- The shape and size of a lake and its basin.

Littoral- The area of a lake shallow enough for submerged aquatic plants to grow.

Meromixis- The condition where the entire lake fails to circulate to its deepest points; caused by a high concentration of salt in the deeper waters, and by pecu-

liar landscapes (small deep lakes surrounded by hills and/or forests. (Contrast holomixis.)

Mesotrophy- The lake trophic state intermediate between oligotrophy and eutrophy. Algal production is moderate, and chlorophyll a , Secchi disk depth, and total phosphorus are also moderate. These lakes are esthetically "fair" but not as good as oligotrophic lakes.

Metalimnion- The "middle" layer of the lake during periods of summer thermal stratification. Usually defined as the region where the water temperature changes at least one degree per meter depth. Also called the thermocline.

Mixis- Periods of lakewater mixing or circulation.

Mixotrophy- The lake condition where the water is highly stained with humic acids, but algal production and chlorophyll a values are also high.

Oligotrophy- The lake trophic state where algal production is low, Secchi disk depth is deep, and chlorophyll a and total phosphorus are low. Esthetically these lakes are the "best" because they are clear and have a minimum of algae and aquatic plants. Deep oligotrophic lakes can usually support cold-water fish such as lake trout and land-locked salmon.

Overturn- See circulation or mixis

pH- A measure of the hydrogen ion concentration of a liquid. For every decrease of 1 pH unit, the hydrogen ion concentration increases 10 times. Symbolically, the pH value is the "negative logarithm" of the hydrogen ion concentration. For example, a pH of 5 represents a hydrogen ion concentration of 10^{-5} molar. [Please thank the chemists for this lovely symbolism -- and ask them to explain it in lay terms!] In any event, the higher the pH value, the lower the hydrogen ion concentration. The range is 0 to 14, with 7 being neutral 1 denoting high acid condition and 14 denoting very basic condition.

Photosynthesis- The process by which plants convert the inorganic substances carbon dioxide and water into organic glucose (sugar) and oxygen using sunlight as the energy source. Glucose is an energy source for growth, reproduction, and maintenance of almost all life forms.

Phytoplankton- Microscopic algae which are suspended in the "open water" zone of lakes and ponds. A major source of food for zooplankton. Common examples include: diatoms, euglenoids, dinoflagellates, and many others. Usually included are the blue-green bacteria.

Parts per million- Also known as "ppm". This is a method of expressing the amount of one substance (solute) dissolved in another (solvent). For example, a solution with 10 ppm of oxygen has 10 pounds of oxygen for every 999,990 pounds (500 tons) of water. Domestic sewage usually contains from 2 to 10 ppm phosphorus.

Parts per billion- Also known as "ppb". This is only 1/1000 of ppm, therefore much less concentrated. As little as 1 ppb of phosphorus will sustain growth of

algae. As little as 10 ppb phosphorus will cause algal blooms! Think of the ratio as 1 milligram (1/28000 of an ounce) of phosphorus in 25 barrels of water (55 gallon drums)! Or, 1 gallon of septic waste diluted into 10,000 gallons of lakewater. It adds up fast!

Plankton- Community of microorganisms that live suspended in the water column, not attached to the bottom sediments or aquatic plants. See also "bacterioplankton" (bacteria), "phytoplankton" (algae) and "zooplankton" (microcrustaceans and rotifers).

Saturated- When a solute (such as water) has dissolved all of a substance that it can. For example, if you add table salt to water, a point is reached where any additional salt fails to dissolve. The water is then said to be saturated with table salt. In lakewater, gaseous oxygen can dissolve, but eventually the water becomes saturated with oxygen if exposed sufficiently long to the atmosphere or another source of oxygen.

Specific Conductivity- A measure of the amount of salt present in lakewater. As the salt concentration increases, so does the specific conductivity (electrical conductivity).

Stratum- A layer or "blanket". Can be used to refer to one of the major layers of lakewater such as the epilimnion, or to any layers of organisms or chemicals that may be present in a lake.

Thermal Stratification- The process by which layers are built up in the lake due to heating by the sun and partial mixing by wind.

Thermocline- Region of temperature change. (See metalimnion.)

Total Phosphorus- A measure of the concentration of phosphorus in lakewater. Includes both free forms (dissolved), and chemically combined form (as in living tissue, or in dead but suspended organisms).

Trophic Status- A classification system placing lakes into similar groups according to their amount of algal production. (See Oligotrophy, Mesotrophy, Eutrophy, Mixotrophy, and Dystrophy for definitions of the major categories)

Z- A symbol used by limnologists as an abbreviation for depth.

Zooplankton- Microscopic animals in the planktonic community. Some are called "water fleas", but most are known by their scientific names. Scientific names include: *Daphnia*, *Cyclops*, *Bosmina*, and *Kellicottia*.